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JAPANESE MICROSCOPE

OF TODAY

FEBRUARY 1951

Published by
The Government Mechanical Laboratory,
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Summary of

"REPORT OF MECHANICAL LABORATORY No. 1"

Optical Laboratory

February 1951

Published by
The Government Mechanical Laboratory,
The Agency of Industrial Science and Technology
Sumiyoshi-cho, Suginami-ku, Tokyo
Japan

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PREFACE

The reconstruction of Japan as a peace-loving nation requires the development of all industries and the increased production of fine articles. Fortunately remarkable progress has been made in the manufacture of microscopes since the end of the war.

Finding it urgently necessary to improve the quality of microscopes and promote their exportation, our Government organized an inspection committee in the Ministry of International Trade and Industry, and the inspection was carried out by the committee in our laboratory in September, 1949.

The results of the inspection were reported in February, 1950. This pamphlet is a summary of that report.

We are sure that this will be of service to show how earnestly and eagerly the microscope manufactureres of our country are trying to make their product better.

Our best thanks are due to Dr. Kogoro Yamada, former fellow of the Institute of Physics and former fellow of the Physical Society (London), who has kindly helped us in offering this pamphlet to the English-speaking world.

February, 1951.

Yukichi UKITA
Chief of the Opitical Laboratory

I. Short History of Manufacture of Microscopes in Japan

First Trial Manufacture. It was 1910 when the late Shinkichi Shindo and the late Kakichi Kato jointly undertook to manufacture a microscope, its stand being made in the Shindo Works and its optical parts in the Kato Optical Works. By their strenuous effort, the first trial manufacture was completed in 1912. As it was taken after Leitz's Microscope Type N, it had three objectives of magnifying power 8 x, 10 x and 63 x and three eyepieces of 5 x, 8 x and 10 x ; consequently the total magnification was 600 x.

M. KATERA In 1914, this microscope was put in the mass production backed by Fukumatsu Matsumoto and a trade name M. KATERA was given to it.

Before the advent of a microscope thus made in Japan, microscopes were imported from Germany, British Isles, the United States of America and Austria. The outbreak of the World War I in 1914, however, prevented us to import them and yet their demand was increased both at home and in the Republic of China. Their factory was, therefore, expanded to meet the demand.

KALNEW During the period from 1915 until 1918, an oil immersion objective 1″/12(100 x) and an eyepiece #5(12 x) were made. As far as the mechanical portions are concerned, a fine adjustment of worm-gear systam, simple mechanical stage and an illuminatnig apparatus were made. And another trade name KALNEW was introduced.

In 1924, however, above mentioned Shindo and Kato dissolved their joint enterprises and Shindo began to manufacture M. KATERA type while Kato was to manufacture KALNEW type.

In 1929, M. KATERA Microscope which was first made by taking Leitz's N Type as model, was changed to take after Carl Zeiss type ; since then, objectives of 3 x, 10 x, 40 x and oil immersion 100 x as well as eyepieces of 3 x, 5 x, 7 x, 10 x and 15 x are being made. The fine adjustment was also changed to Mayer type. Later on this works was called Tiyoda Optical Co. Ltd.

OLYMPUS In 1919, another microscope manufacturing company called Takachiho Works Ltd. was established by Cho Yamashita and its products had a trade name OLYMPUS. Later on, Takachiho Works Ltd. has changed its trade name to Olympus Optical Co. Ltd.

SUMP In 1939, Cho Yamashita retired from the said works and newly established Nisshin Optical Instrument Co. Ltd., where SUMP microscopes are manufactured.

YASHIMA In 1935, Kunisaburo Nishino and others established Yashima Optical Co. Ltd., where they began to manufacture YASHIMA microscopes.

JOICO The Japan Optical Co. Ltd. must also be mentioned here as a manufacturer of microscope JOICO. In 1908, the late Ryuzo Fujii established an optical works with his younger brother Kozo Fujii to manufacture binoculars and telescopes. In 1917, however, it was merged by the newly established Japan Optical Co. Ltd. Although the main product of the company was optical weapons for war, it also manufactured microscopes whose trade name was JOICO. Inspite of the large capital, the company has not sent so many microscopes to the market. But now it manufacture a new model NIPPON KOGAKU.

Development. During the period from 1910 until 1930, the microscope industry in Japan has established a firm foundation and since then it expanded its manufacture to a metallurgical microscope, polarization microscope, dark-field illuminating microscope, photo-microscopic apparatus. And as for optical part, semiapochromat, apochromat and compensating eyepiece were made.

Since the outbreak of the Manchurian Incident, the rise of the precision mechanical industry in Japan has encouraged the manufacture of microscopic apparatus and furthermore, microscopic measuring instrument, projection microscope, binocular microscope, ultra-microscope, large type photo-microscopic apparatus had been manufactured.

Regretably, the outbreak of the World War II prevented the manufacture of microscopes. But after the end of the war, the microscope industry was recognized as one of the key industries to reconstruct Japan and to develop here a state dedicated, in full reality, to the welfare of the people.

Accordingly, the former microscope makers aroused themselves to meet this requirement. They met, however, with many obstacles to re-establish their microscope industry. Especially the social disorder and economic collapse that followed defeat prevented them to make a push to their new aim. Nevertheless, they have never been discouraged. Lens polishing machines were being turned in war-torn workshops. Lathes and milling machines were busily driven to form parts of microscope inspite of having beem interrupted by frequent blackout of electricity. Yet, the workmen were never daunted. At last fruits were reaped from their strenuous effort.

In January 1946, just after five months since the end of the war, the first microscope elaborated after the war appeared in the market. It was, indeed, the dawn of the new era of our microscope industry.

Annual Production. According to the investigation of the Optical Precision Instrument Industrial Association, the annual product at the post-war times is as follows:-

Year	Quantity	Amount of Money
1946	2,600	¥ 9,400,000
1947	7,200	¥ 38,000,000
1948	21,500	¥ 135,000,000
1949	26,500	¥ 245,000,000

At the rebirth of this industry, the utmost importance is attached to the manufacture of large type microscopes for medical purposes whose magnifying power was 600-1500. In 1948, however, as the result of the release of the new educational system as well as the rise of small factories, a great number of medium type microscope (400-600 x) were demanded. Furthermore, small type microscope (100-300 x) for children was also produced. It may be not out of place to mention here that the number of products in 1941 when the war was broken out, was 12,000. Thus the quantity of production in 1948 has already outnumbered that in 1941, the maximum record in the prewar times.

Export. In the pre-war times, most microscopes were exported to the Republic of China. But owing to the strenuous effort of the makers to improve their post-war products, buyers from Allied Powers recognized the worth of microscopes made in occupied Japan. Consequently, 2,000 sets of microscopes and 1,300 pieces of their accessories were exported during 1949 which amounted to $ 93,000 FOB. Especially 85% of them was exported to American continents, 9% to India and Africa and 6% to Southern area.

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II. Japanese Engineering Standard Specifications for Microscope

1. Introduction

In the course of time after the opening of manufacture of microscopes, the Japanese microscope industrialists directed their attention to the improvement of their products one after another and also to the manufacture in accordance with a certain standard.

In June 1942, the Microscope Sub-committee headed by Motohiko Furuya was established in the Precision Instruments Control Association which worked out a standard after about two years.

As soon as the war ended, all the Japanese people have been emancipated from the military control and began to pursue the way of reconstruction of peaceful Japan. Hereupon the microscope industrialists concentrated their energy to manufacture microscopes chiefly for export. For that purpose a standard specification was required to manufacture microscopes on the international footing. In these circumstances, on 13 January, 1947, the Microscope Committee headed by Shinkichi Shindo was established in the Optical Precision Instruments Industrial Association. The draft of standard specifications for microscope worked out by the said Committee was submitted to Engineering Standard Investigation Committee which, on 21 July, 1947, set up the Microscope Subcommittee in order to investigate whether the said standard can be adopted as Japanese Engineering Standard Specification or not. This subcommittee was headed by Hiroshi Kubota, Professor of Tokyo University, and consisted of 12 industrialists, 9 scholars, 11 Government officials as committee-members and another 10 members as assistants. The subcommittee convened thirteen times and the final discussion was made on 18 March, 1948 and eventually definite specifications for microscopes were prepared of which I'll mention in detail. This is, indeed, a great step in a forward direction for the optical manufactures.

It is here not without interest to mention that two new test-specimens were made by the Committee. They are of the same principle as that of the Abbe test-plate ruled with fine lines. But the process of manufacture of these test-specimens is quite different from it, which was accomplished under the cooperation of Tokyo Univ., Fuji-kasei Co. and Tiyoda Opt. Co.

The method is as follows. First the replica of plane diffraction grating with 300/mm and 600/mm were made by the new method using methylmethacrylic acid. Then the shadows of the grooves of replica are made by evaporating silver or aluminium metal onto them in vacuum obliquely. Thus a parallel array of transparent and opaque lines with very narrow interval is obtained. Finally it is printed on the photographic plate with very fine grains. The result was excellent and the final plate was called a *test-specimen*.

Mention must also be made of the classification of microscopes in accordance with their sizes. A microscope, mechanical tube length of which is longer than 160 mm is classified as a large-sized model; a microscope, mechanical tube length of which is from 140 to 160 mm is classified as a medium-sized model; and finally a microscope, mechanical tube lengh of which is shorter than 140 mm is classified as a small-sized model.

As for the diameter of screw-thread, the core thread, the effective diameter, the pitch and the number of threads to the inch of the objective, the Committee adopted the Specification decided by the Royal Microscopical Society believing that "the adoption by all opticians of this regulation size constitutes a very great convenience, seeing that it enables the microscopist to interchange objectives without the necessity of employing supplemental adapter to suit the special requirements of each other" (Edmund J. Spitta, Microscopy (1920), p. 56.)

The drafts of standard specifications prepared by the committee were revised in order to meet the items stipulated in the Export Goods Control Law and finally they were enacted as JES as of 1 st October, 1948. They are as follows:

JES Mech. 7131, General provisions of testing microscopes.

JES B 7132, Large-sized microscopes. (Revised on 26 Dec. 1949)

JES Mech. 7133, Medium-sized microscopes.

JES Mech. 7134, Small-sized microscopes. (Revised on 26 March, 1949)

JES Mech. 7140, Microscope test-specimen.

JES Mech. 7141, Screw of microscope objective.

JES Mech. 7142, Screwed parts of microscope objective and body-tube.

JES Mech. 7143, Microscope eyepiece and its engagement with eyepiece sleeve.

JES Mech. 7144, Microscope condenser for transmitted light and its engagement with substage sleeve.

JES Mech, 7145. Mechanical stage, its fixing knock and screw.

JES Mech. 7146, Clip and its fixing.

JES Mech. 7147, Revolving nosepiece of microscope.

JES Mech. 7148, Slide glass and cover glass.

JES Mech. 7149, 1/10 mm eyepiece micrometer for microscope.

As the result of completion of mission, the committee was dissolved, but a new Microscope Committee headed by Hiroshi Kubota was established in the Precision Instrument Department of the Japan Industrial Standard Investigation Council.

Now mention must be made of most important standard specifications among these 14.

2. JES, B 7132 for Large-sized Microscope.

Chapter I. General Provisions

1.1. This specification is provided for microscopes(1) having a mechanical tube length of 160 mm or longer and carrying the fine adjustment (hereinafter referred to as microscope).

This specification may also be applied to the export microscopes.

Note (1).-The specification is applicable to those, mechanical tube length of which is shorter than 160 mm as the result of insertion of either lenses or prisms between the objective and the eyepiece in so far as their magnifications remain unchanged.

1.2. The quality of microscope is classified into two classes, viz., the 1st class and the 2nd class.

1.3. Engraving shall be made in the following manner: trade mark and number of manufacture on the stand of microscope; magnification, numerical aperture and trade mark on the objective; magnification and trade mark on the eyepiece; numerical aperture on the condenser respectively.

Furthermore a magnification table shall be attached to each microscope which contains the description of mechanical tube length, nominal magnification and other necessary matters.

Chapter II. Construction and Performance

2.1. Every part shall be made of materials of sufficient strength and good durability, processed and constructed with utmost carefulness in order to fulfil following provisions.

(1) Both the painting and plating of every part must be strong enough lest it is decolorised, worn off or apt to rust.

(2) Both coarse and fine adjustments shall operate easily and smoothly without backlash and

withstand prolonged usage without working loose.

(3) The adjustment of perpendicularity of the body tube to the stage and of centering of the body tube with the condenser sleeve shall be carried out with much attention in order to make a microscope to display full power as a whole.

(4) The stage shall be of such a construction that a slide glass made in accordance with the provisions of JES Mech. 7148 can be used.

(5) All the accessories described in the "Accessories Combination Table" shall make a complete set and their combinations be in good order.

2.2. Screw of the objective mount, screw parts of the objective and revolving nosepiece, the fitting parts of eyepiece and eyepiece sleeve, those of condenser and condenser sleeve(1), knock and screw for the mechanical stage and clip shall be made in accordance with provisions of JES Mech. 7141–7146 respectively.

Note (1).–This provision is not applicable to a microscope used as dry system alone and also to special microscopes.

2.3. The allowances of magnification, numerical aperture and eccentricity at the object plane are shown in the Table I.

(JES B 7132) Table I.

Classification		1 st class	2 nd class
Magnification		±5%	±8%
Numerical aperture (with the exception of those of nominal magnification less than 10x)		−4%	−8%
Minimum nominal numerical aperture	Nominal magnification : 100x or more 40x or more 10x or more	 1.25 or more 0.65 or more 0.25 or more	 1.25 or more 0.65 or more 0.25 or more
Eccentricity at the object plane	Nominal magnification : 100x or more 40x or more 10x or more	 0.05 mm or less 0.08 mm or less 0.10 mm or less	 0.10 mm or less 0.15 mm or less 0.20 mm or less

Remark 1. For any other magnifications, the minimum nominal numerical aperture is calculated from the data of the table assuming that a linear relation exists between magnification and numerical aperture.

Remark 2. All the objectives used for transparent objects are required to have sufficient free working distances so as to be able to test objects under cover–glass of 0.17 mm in thickness; dry objectives, especially those having magnifications from 35 to 45, are required to have sufficient free working distances so as to be able to test objects under cover–glass of 0.4 mm in thickness.

2.4. Allowances of magnification and field number(1) of eyepiece are shown in Table II.

(JES B 7132) Table II.

Classification	1st class	2 nd class
Magnification	±5%	±8%
Field number	135/(magnification+2) or more	120/(magnification+2) or more

Note (1). Field number of an eyepiece means the diameter of an image expressed in mm of a field diaphragm formed by a lens in front of it.

2.5. Allowance of numerical aperture of a condenser used for transparent objects are shown in Table III.

(JES B 7132) Table III.

Classification	Numerical aperture in bright field	Numerical aperture in dark field	
		Inside	Outside–Inside
1 st class 2 nd class	±0.10 ±0.15	Nominal N. A. ±0.05	0.1 or more

2.6. The allowance of the total eccentricity of the objective revolver or objective changer shall be 0.03 mm or less at the object plane for the 1 st class microscope and 0.05 mm or less for the 2 nd class one exclusive of the eccentricity of the objective itself.

2.7. The microscope having a revolving nosepiece which carries two or more objectives of nominal magnifications 10 x or more shall produce an image within the limit of adjustment stipulated in the Table IV, when the nosepiece is turned from the low power objective to the high power one.

(JES B 7132) Table IV.

Classification	1 st class	2 nd class
In case of dry systems alone	±0.1 mm	±0.15 mm
In case immersion system is used	From −0.1 mm to −0.4 mm	From −0.05 mm to −0.6 mm

2.8. The allowance of total eccentricity given rise to by both objectives having magnification of 10 x or more and a nosepiece shall be 0.06 mm or less.

2.9. In case of testing objectives by using a test-specimen made in accordance with the provisions of JES Mech. 7140 and an eyepiece of field number 12 by the aid of white light, the area clearly seen simultaneously with the central portion of the field without either chromatic aberration or distortion in practically inadmissible extent as well as an area clearly seen as the result of operating fine adjustment are shown in Table V.

(JES B 7132) Table V.

Classification	Nominal numerical aperture of objective	Area to be seen clearly	
		1 st class	2 nd class
Simultaneously with central portion	0.20 or more and less than 0.40	50% or more from the center of the field	45% or more from the center of the field
	0.40 or more and less than 1.00	40% or more from the center of the field	35% or more from the center of the field
	1.00 or more	30% or more from the center of the field	25% or more from the center of the field

Classification	Nominal numerical aperture of objective	Area to be seen clearly	
		1st class	2nd class
After having been adjusted	0.20 or more and less than 0.40	80% or more of the field	70% or more of the field
	0.40 or more and less than 1.00	65% or more of the field	55% or more of the field
	1.00 or more	50% or more of the field	40% or more of the field

Remark : In case of an objective having a nominal numerical aperture of less than 0.40, the 1st kind of test-specimen shall be used ; in case of an objective having a nominal numerical aperture of 0.40 or more and less than 1.00, the 2nd kind of test-specimen shall be used ; in these both cases, outline of the lines of the test-specimens shall be observed. Finally in case of an objective having nominal numerical aperture of 1.00 or more, 2nd kind of test-specimen shall be used and details of the lines of the test-specimens shall be observed.

Chapter III. Testing

3.1. Testing shall be carried out with respect to exterior appearance, function of mechanical portions, dimensions of parts, capability of optical parts and performance as a whole. General matters relating to the testing shall be referred to JES Mech. 7131.

3.2. Testing with respect to exterior appearance and function of mechanical portions shall be carried out for finished goods and they must come up to the provisions of Article *2.1.*

3.3. Testing of dimensions of parts shall be carried out with respect to the screw of objective, screw parts of objective, body tube and revolving nosepiece, fitting parts of eyepiece and eyepiece sleeve, those of condenser and condenser sleeve as well as clip. They must come up to the provisions in Article *2.2.*

3.4. As for capability of optical parts and performance as a whole, test shall be carried out in accordance with the following provisions :

(1) Objective, eyepiece, condenser used for transparent object, and either objective revolver or objective changer are required to come up to the provisions stipulated in Articles *2.3~2.8.*

(2) Finished goods are required to come up to provisions of Article *2.9.*

3. JES Mech. 7133 for Medium-sized Microscope.

Chapter I. General Provisions.

§ *1.* This specification is provided for microscopes(1) having mechanical tube length of 140 mm or more which do not belong to the category of large-sized ones stipulated in JES B 7132. This specification may also be applied to the export microscopes.

Note (1):- This specification is applicable to those having mechanical tube length shorter than 140 mm as the result of insertion of either lenses or prisms between the objective and the eyepiece in so far as their magnifications remain unchanged.

§ *2.* The quality of microscope is classified into two classes, viz., the 1st class and the 2nd class.

Engraving shall be made in the following manner:- Trade mark and number of manufacture on the stand of a microscope ; magnification, numerical aperture and trade mark on the objective ; magnification and trade mark on the eyepiece ; numerical aperture on the condenser.

Furthermore a magnification table shall be attached to each microscope which contains the description of mechanical tube length, nominal magnification and other necessary matters.

Chapter II. Construction and Performance.

§ *4.* Every part shall be made of materials of sufficient strength and good durability, processed and constructed with utmost carefulness paying special attention so as to have fine exterior appearance and good mechanical efficiency and also following provisions must be fulfilled.

(1) Every part shall operate easily and smoothly without showing any sign of wear and tear, and have a good mechanical efficiency which promises to make the microscope to display its overall efficiency to the full extent.

(2) The stage shall be of such a construction that a slide glass made in accordance with the provisions of JES Mech. 7148 can be used.

(3) All the accessories described in the "Accessories Combination Table" shall make a complete set and their combinations must be in good order.

§ *5.* Screw of the objective cell, screw parts of the objective and nosepiece, the fitting parts of eyepiece and eyepiece sleeve shall be made in accordance with the provisions of JES Mech. 7141~7146 respectively.

§ *6.* The allowances of magnification, numerical aperture and eccentricity at the object plane are shown in Table I.

(JES Mech. 7133) Table I.

Classification		1 st Class	2 nd Class
Magnification		± 7 %	±12%
Numerical aperture (with the exception of objectives of nominal magnification of less than 10)		− 8 %	−12%
Minimum nominal numerical aperture	Nominal magnification: 100 x or more 40 x or more 10 x or more	 1.2 or more 0.6 or more 0.2 or more	 1.2 or more 0.6 or more 0.2 or more
Eccentricity at the object plane	Nominal magnification: 100 x or more 40 x or more 10 x or more	 0.08 mm or less 0.12 mm or less 0.15 mm or less	

Remark 1. For any other magnifications, the minimum nominal aperture is calculated from the data of the table assuming that a linear relation exists between magnification and numerical aperture.

Remark 2. All the objectives used for transparent objects are required to have sufficient free working distances so as to be able to test objects under cover-glass of 0.17 mm in thickness; dry objectives, especially those having magnifications from 35 to 45, are required to have sufficient free working distances so as to be able to test objects under cover-glass of 0.4 mm in thickness.

§ *7.* Allowances of magnification and field number(1) of eyepiece are shown in Table II.

(JES Mech. 7133) Table II.

Classification	1 st class	2 nd class
Magnification	± 7 %	±12%
Field number	125/(magnification+2) or more	110/(magnification+2) or more

Note (1). Field number of an eyepiece means the diameter of an image expressed in mm of a field diaphragm formed by a lens in front of it.

§ *8*. The allowance of the total eccentricity of objective revolver or objective changer shall be 0.05 mm or less at the object plane for the 1st class microscope exclusive of the eccentricity of objective itself.

§ *9*. In case of testing objectives by using a test-specimen stipulated in JES Mech. 7140 and an eyepiecce of field number 12 by the aid of white light, the area clearly seen simultaneously with the central portion of the field, free from either chromatic aberration or distortion in practically inadmissible extent as well as an area clearly seen as the result of operating focussing adjustment knob are shown in Table III.

(JES Mech. 7133) Table III.

Classification	Nominal numerical aperture of objective	Area to be seen clearly	
		1 st class	2 nd class
Simultaneously	0.20 or more and less than 0.40	45% or more from the center of the field	40% or more from the center of the field
with central portion	0.40 or more and less than 1.00	35% or more from the center of the field	25% or more from the center of the field
After having been adjusted	0.20 or more and less than 0.40	70% or more of the field	60% or more of the field
	0.40 or more and less than 1.00	55% or more of the field	40% or more of the field

Remark : In case of an objective having a numerical aperture of less than 0.40, 1 st kind of test-specimen shall be used ; in case of an objective having a nominal numerical aperture of 0.40 or more and less than 1.00, 2 nd kind of test-specimen shall used ; in these both cases, outline of the lines of test-specimens shall be observed.

Chapter III. Testing.

§ *10*. Testing shall be carried out with respect to exterior appearance, function of mechanical portion, dimensions of parts, capability of optical parts and performance as a whole. General matters relating testing shall be referred to JES Mech. 7131.

§ *11*. Testing with respect to exterior appearance and function of mechanical portions shall be carried out for finished goods and they must come up to the provisions of Articles from *3* to *8*.

§ *12*. Testing of dimensions of parts shall be carried out with respect to the screw of objective, screw parts of objective, body tube and revolving nesepiece, fitting parts of eyepiece and eyepiece sleeve only for the 1 st class goods. They must come up to the provisions of Article *8*.

§ *13*. As for capability of optical parts and performance as a whole, test shall be carried out in accordance with the following provisions :

(1) Objective and eyepiece are required to come up to the provisions of Articles *6* and *7* respectively (for goods taken at random).

(2) In case of the 1 st class goods, function of mechanical portions of either objective revolver or objective changer is required to come up to the provision of Article *8* (for goods taken at random.)

(3) Finished goods are required to come up to the provision of Article *9*.

4. JES Mech. 7134 for Small-sized Microscope.

Chapter I. General Provisions.

§ *1*. This specification is provided for microscopes(1) of mechanical tube length of 80 mm or more which belong to neither large-sized microscopes provided in JES B 7132 nor medium-sized microscopes provided in JES Mech. 7133 (hereinafter referred to as microscope.) Furthermore, this specification is applicable to the export microscopes.

Note (1). This specification is also applicable to those having mechanical tube length shorter than 80 mm as the result of insertion of either lenses or prisms between objective and eyepiece in so far as their magnifications remain unchanged.

§ *2*. The quality of microscope is classified into two classes, viz., the 1st class and the 2nd class.

§ *3*. Total magnification, trade mark and number of manufacture shall be engraved on the microscope. As for the magnification, however, magnifications or designations of eyepiece and objective can be separately engraved on them respectively. In the latter case, total magnification table must be attached.

Chapter II. Construction and Performance.

§ *4*. Every part shall be made of materials of sufficient strength and good durability, and processed and constructed with utmost carefulness paying special attention to attain good mechanical function and in such a way that every movable part operates easily and smoothly. Moreover, the stage must be of such a construction that a slide glass made in accordance with the provisions of JES Mech. 7148 can be used.

§ *5*. The allowance of the total magnification shall be ±20% for the 1 st class microscope and ±30% for the 2 nd class one.

§ *6*. In case of testing by using 1 st kind of test-specimen made in accordance with provisions of JES Mech. 7140 by the aid of white light, there shall be no chromatic aberration to practically inadmissible extent and the lines must be resolved cleary in the central portion of the field. Furthermore, in case of the 1 st class goods, it is required that the lines are to be clearly resolved.

Chapter III. Testing.

§ *7*. Testing shall be carried out with respect to exterior appearance, function of mechanical portions, capability of optical parts and performance as a whole. General matters relating to the testing shall be referred to JES Mech. 7131.

§ *8*. Testing with respect to exterior appearance and function of mechanical portions shall be carried out for finished goods and they must come up to the provisions of Articles *3*, and *4*.

§ *9*. Testing shall be carried out with respect to capability of optical parts and performance as a whole and they are required to come up to the provisions of Articles *5* and *6*.

III. Inspection of Performance of Microscopes made in Japan

1. Inspection Committee

In 1949, International Trade and Machinery Bureau of International Trade and Industry Ministry took the initiative to draw up a plan to develop the export of microscopes by spurring microscopic industrialists on to effort to improve furthermore their products. The Government Mechanical Laboratory of the Agency of Industrial Science and Technology and other laboratories concerned were called in to help the job. The authorities concerned were of opinion that, first of all, it was necessary to examine all the microscopes made in Japan in accordance with the Japanese Engineering Standard Specifications for Microscope just put into effect. Thus an Inspection Committee and Inspection Committee of Technical Experts were established. Their members were as follows:

Inspection Committee : Chairman : Makoto Ogoshi. (Director of the Government Mechanical Laboratory). Deputy chairman : Taro Isono (Chief of Section of Agricultural, Forestry and Public Welfare Machinery, International Trade and Machinery Bureau). Committee-members : Konosuke Okabe (International Trade and Machinery Bureau), Noribumi Kumagai (International Trade and Promotion Bureau), Ichibei Terazawa (Machines and Implements Conditioning House), Hidehiko Higashi (Standard Department, Agency of Industrial Science and Technology), Kan'ichi Asagoe (Osaka Industrial Laboratory), Hiroshi Hasunuma (Government Mechanical Laboratory), Yukichi Ukita (Government Mechanical Laboratory), Ryuichi Hioki (First Engineering Department, Tokyo University), Hiroshi Kubota (Second Engineering Department, Tokyo University), Shiro Tojo (Optical Precision Instruments Industrial Association), Kazuo Koba (Education Ministry), Rinjiro Sasagawa (Welfare Ministry).

Committee Members of Inspection Committee of Technical Experts : Kosaburo Aoki (Yashima Optical Co. Ltd.), Motohiko Furuya (Olympus Optical Co. Ltd.), Takateru Koakimoto (Japan Optical Co. Ltd.), Gen Kurosawa (Tiyoda Optical Co. Ltd.), Tadashi Shimojima (Tokyo Optical Co. Ltd.), Minoru Kubota (Nisshin Optical Precision Instrument Co. Ltd.), Shiro Tojo (Optical Precision Instruments Industrial Association), Hidehiko Higashi (Standard Department, Agency of Industrial Science and Technology), Ryuichi Hioki (First Engineering Department, Tokyo University), Hiroshi Kubota (Second Engineering Department, Tokyo University), Konosuke Okabe (Machines and Implements Conditioning House), Yukichi Ukita, Michiyuki Masaki and Yasuhiro Doi (all of these three from Government Mechanical Laboratory).

2. Items of Inspection and Methods of Testing

Methods of Testing First of all, the committee drew up a plan for the methods of testing and then determined particulars of concrete method as well as standard for marking in accordance with specifications for export goods. Appendix TABLE I shows items to be tested, methods of testing, scope of application and standards for classification. Following items, however, were not taken into consideration by the committee:-

(a) quality of materials, (b) durability, (c) excellency of design, (d) workmanship.

3. Marking and Classification

Exterior appearance, dimensions of parts, function of mechanical portion, capability of optical parts and performance as a whole were taken as objects of inspection, each of which was divided into smaller items. There are three kinds of microscopes, i.e., large-, medium- and small-sized models in accordance with JES as mentioned above. Large-sized model was further classified into A-, B- and C-types according to the grade of function of mechanical portion and capability of optical parts:-

Type A. Large-sized microscope equipped with oil immersion system, Abbe condenser and Mayer fine adjustment.

Type B. Large-sized microscope equipped with oil immersion system, condenser and fine adjustment of any type whatever.

Type C. Large-sized microscope without oil immersion system but equipped with rotating diaphragm and fine adjustment.

Standard points for each item are shown in the Table 1. The Table makes it clear that on what portion of microscope much emphasis is laid. The results shall not be compared with absolute value of marks obtained but with their percentage with respect to these standard points.

In accordance with JES B 7132, the quality of microscope is classified into two classes, viz., the 1st class and the 2nd class. They are determined by the marks obtained as to items specified in Articles. As for the items which are not stipulated in JES, the microscope is divided into Class A and Class B corresponding to the 1st and 2nd class respectively, The microscope which is given less marks than those of Class B is graded as Class C.

Table 1. Items of Inspection and Standard Points

Item	Classification at large	Large-size A	Large-size B	Large-size C	Medium-size	Small-size
Exterior appearance		50	50	45	45	45
Dimension of parts		50	50	35	35	5
Function of mechanical portion	coarse adjustment	70	70	70	70	60
	fine adjustment	85	75	75	—	—
	revolver	40	40	40	20	—
	stage	50	40	10	5	10
	illuminating apparatus	50	35	25	15	—
	inclination of limb	5	5	5	5	5
	total	300	265	225	115	75
Capability of optical parts	objective	140	130	80	80	23
	eyepiece	65	39	52	39	
	condenser	20	20	—	—	—
	total	225	189	132	119	23
Performance as a whole	total eccentricity	100	70	70	70	—
	parfocality	20	20	10	10	—
	definition	240	220	140	140	40
	total	360	310	220	220	40
The sum total		985	864	657	534	188

The standard points qualified for classes A and B are shown in Table 2.

Table 2. Classification by Quality and Standard Points

Items \ Classification by quality		Large-size A	Large-size B	Medium-size A	Medium-size B	Small-size A	Small-size B
Exterior appearance		85	70	80	60	80	60
Dimension of parts		85	0	80	0	80	0
Function of mechanical portion	coarse adjustment	80	50	80	50	70	40
	fine adj. Mayer	85	60	—	—	—	—
	fine adj. others	70	40	—	—	—	—
	revolver	100	50	100	50	—	—
	stage	90	70	85	65		
	illuminating apparatus	90	70	85	65	80	60
	inclination of limb	90	70	85	65		
Capability of optical parts	objective	90	50	90	50		
	eyepiece	90	50	90	50	Magnification 90	50
	condenser	90	50	—	—		
Performance as a whole	total eccentricity	JES 1. class	JES 2. class	100	50	—	—
	parfocality	〃	〃	100	50	—	—
	definition	70	50	70	50	70	50

4. Execution of Examination

Microscopes submitted to the committee for examination until the end of August, 1949 amounted to 17 kinds of large-sized model, 3 kinds of medium-sized model and 6 kinds of small-sized model; and moreover 2 kinds of special microscopes. A couple of each kinds were submitted in pursuance of the regulations of the Committee and one of them was taken at random by the committee-member while the other was left to the choice of the makers.

Examination was carried out by the Expert Committee members and several assistants nearly every day from 13 September until 2 October, 1949.

5. Explanation of Special Terms

In order to make the reader to understand well the contents of Appendex TABLE I, following explanation will be of service.

(a) Tester of height of substage. Fig. 1 is the diagram of this tester. A shaded part under the dial gauge represents an organic glass plate. The height of a substage brought under this plate can easily be measured by the aid of the dial gauge.

(b) Eccentricity tester of substage sleeve. This tester is shown in Fig. 2. This is a hollow cylindrical case of metal with the same outer diameter as that of substage. The top plate has a small hole of 0.8 mm in diameter which is exactly situated at the center of the outer surface. Now, fit this tester into the condenser sleeve and examine the eccentricity by using an objective of 10 x and an eyepiece of 10 x.

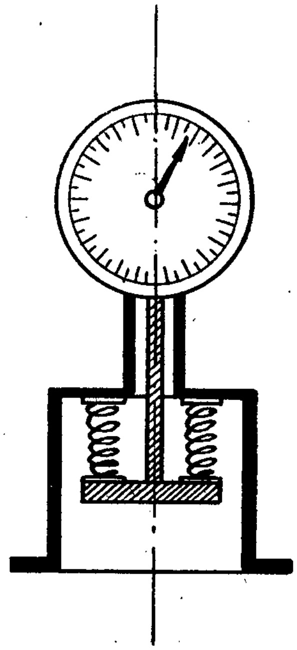

Fig. 1

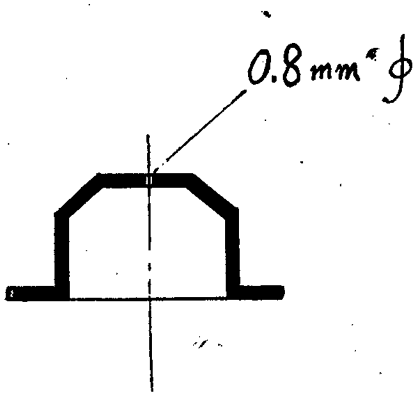

Fig. 2

(c) Standard eyepiece. Standard eyepiece is an eyepiece which has a magnifying power of 10 x and field number of 12.

(d) Perpendicularity of stage tester. The perpendicularity of the stage designates the exactness of the angle between the optical axis of a microscope consisting of an objective and an eyepiece and the surface of the stage which must be right angle.

To examine this perpendicularity, the Committee has made a special tester for this purpose which is shown in Fig. 3. In the figure, A denotes the nosepiece, B the screw part of same and C the stage.

Screw on this implement instead of an objective to the nosepiece and lower the body tube until the tester touches the stage C. Now examine if there is any space between the bottom of the tester and the surface of the stage as shown in Fig. 3. If there is some, measure it with a thickness guage.

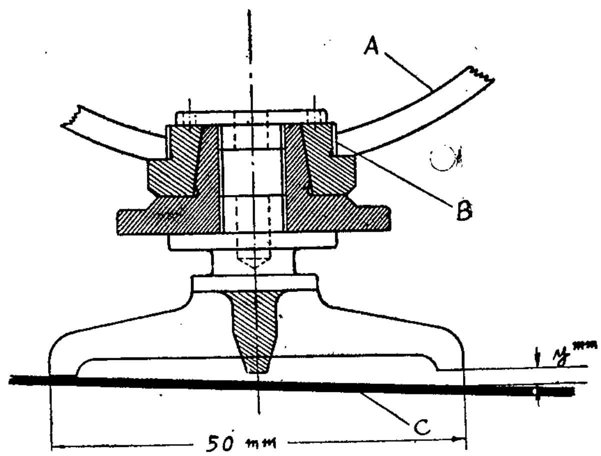

Fig. 3

(e) Fine movement of stage. Fig. 4 shows the mechanism of fine movement of the stage. In the figure, A is a spring, B is a stopper and C is a screw for fine movement of stage.

This function is tested by the aid of 40 x objective, standard eyepiece and test-specimen of the 2 nd kind.

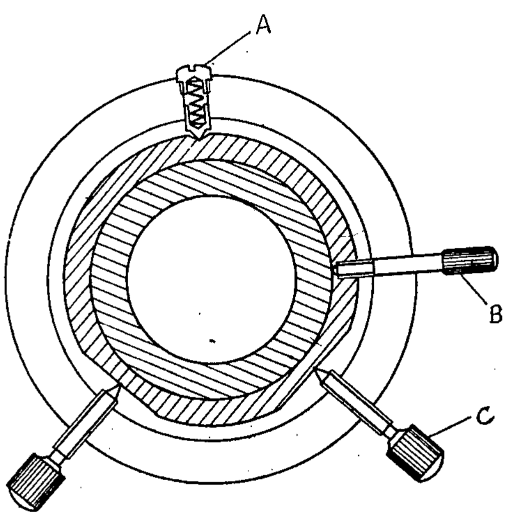

Fig. 4

(f) From side to side motion of mechanical stage. In Fig. 5, D is a milled head which causes the movement in horizontal direction. A is a slide, B is used to press the slide under examination and C is a spring clamp.

(g) Eccentricity of objective measuring apparatus. This apparatus consists of two ring-formed metal-pieces A and B as shown in Fig. 6. These two pieces are rotatable each other without giving rise to any eccentricity. A metal-piece A is screwed on the nosepiece C and an objective D is screwed on the metal-piece B. Now by rotating the objective, its eccentricity can be found if there is any.

(h) Measurement of numerical aperture of the condenser. In Fig. 7, A is an objective, B is a planparallel glass-plate cut, ground and polished in a form of parallelopiped which is placed on the oiled condenser C. D is a collimator which sends parallel rays to the condenser. Then from the side-view of the parallelopiped glass,

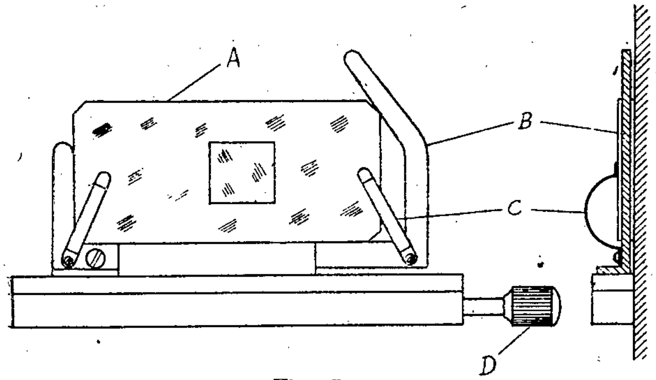

Fig. 5

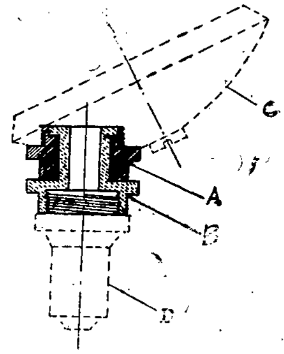

Fig. 6

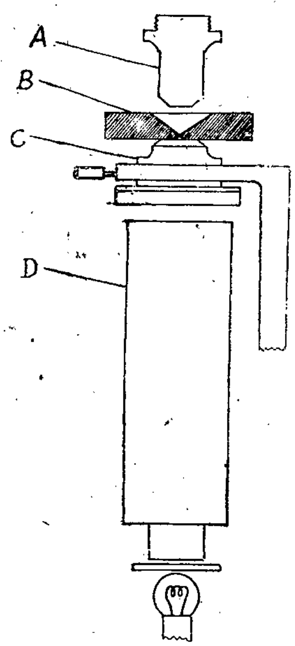

Fig. 7

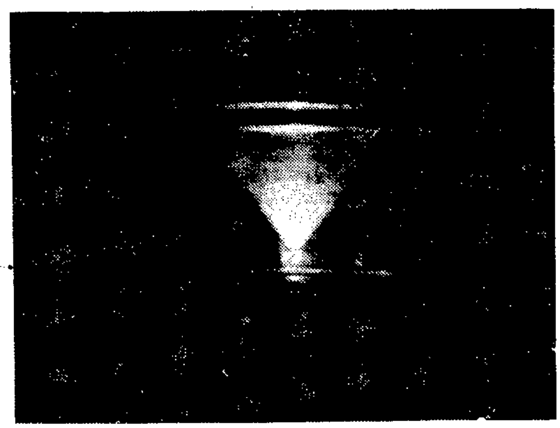

Fig. 8

we can find the aperture angle θ of the cone of rays emerging from the condenser. Fig. 8 shows the photograph of the said side-view from which the angle θ is easily measured. Numerical aperture is obtained by calculating $n \sin \theta/2$.

(i) Total eccentricity. In the microscope attached with a revolving nosepiece, an object brought to the center of the field of one objective does not remain in the center in general, but shifts sidewise when another objective is brought in action by revolving the nosepiece. This is given rise to by the eccentricity of the revolver itself, by the eccentricity of objectives and the deflection of the axis of body tube. Accordingly it is designated "total eccentricity".

6. Summary of the Results of Examination.

(a) Exterior appearance. Of 34 large-sized microscopes submitted to the examination of the Committee, the best one has got 97.6 good points, the second one 97.3, etc. taking 100 points as a full mark. Thus 27 sets were qualified as A class. In the medium-sized model, 5 sets out of 6 were qualified as A class and in the small-sized model, 6 out of 11 as A class.

(b) Dimension of parts. In the large-sized model, 14 sets out of 34 have obtained full marks and 21 sets were qualified as A class. In the medium-sized model, 2 sets out of 6 have obtained full marks and 3 sets out of 6 were qualified as A class.

(c) Coarse adjustment. In the large-sized model, 4 sets of 34 have obtained full marks and 31 sets were qualified as A class. All of the middle-sized model were qualified as A class. In the small-sized model, 6 sets out of 11 were qualified as A class.

(d) Fine adjustment. Among 34 large-sized microscopes, 18 were equipped with fine adjustment of Mayer system and the other 16 with that of simple system. The fine adjustment has been excellently got up and 14 of the former and 13 of the latter were qualified as A class.

(e) Revolving nosepiece. This part is also excellently got up and only 3 out of 36 sets have obtained points inferior to the standard.

(f) Stage. Among 36 large-sized models, 26 were qualified as A class ; all of the medium-sized and 9 of 11 small-sized models were qualified as A class too.

(h) Illuminating apparatus. 24 were qualified as A class out of 34 large-sized models ; 4 medium sized and 3 small-sized models were qualified as A class.

(1) Inclination of limb and stability of stand. 30 large-sized, 2 medium-sized and 7 small-sized models were qualified as A class.

The above descriptions are tabulated in Table 3.

Table 3. Summary of the Results of Examination

Part I. Mechanical Portion

Models	Large-sized			Medium-sized			Small-sized		
Classes	A	B	C	A	B	C	A	B	C
Exterior appearance	27	7	0	5	1	0	6	5	0
Dimension of parts	21	13	0	3	3	0	11	0	0
Coarse adjustment	31	2	1	6	0	0	6	4	1
Fine adjustmdut (Mayer)	14	2	2	—	—	—	—	—	—
// (simple system)	12	4	0	—	—	—	—	—	—
Revolver	30	2	0	4	0	0	—	—	—
Stage	26	8	0	6	0	0	9	1	1
Illuminating apparatus	24	5	5	4	1	1	3	7	1
Inclination of limb	30	2	0	2	4	0	7	2	0

Note:-The figures represent the number of microscopes qualified as A, B and C classes respectively as for each item.

(j) Objective The objectives submitted to the Committee for examination this time were all achromatic and their magnifying powers were as follows :

Models	Magnifying powers
Large-sized, Type A	3~4x, 10x, 40x, 90~100x
Ditto, Type B	10 x, 40 x, 90~100 x
Ditto, Type C and Medium-sized	4~5 x, 10 x, 40 x

Fig. 9 shows the optical systems of these objectives.

(a) 4 x
(b) 10 x, N.A. 0.30
(c) 40 x, N.A. 0.65
(d) 100 x, N.A. 1.25

The objectives were examined in their magnifying power, numerical aperture, eccenticity and working distance. As the result of examination, all the objectives were found very good.

Table 4 shows the summary of the results of examination.

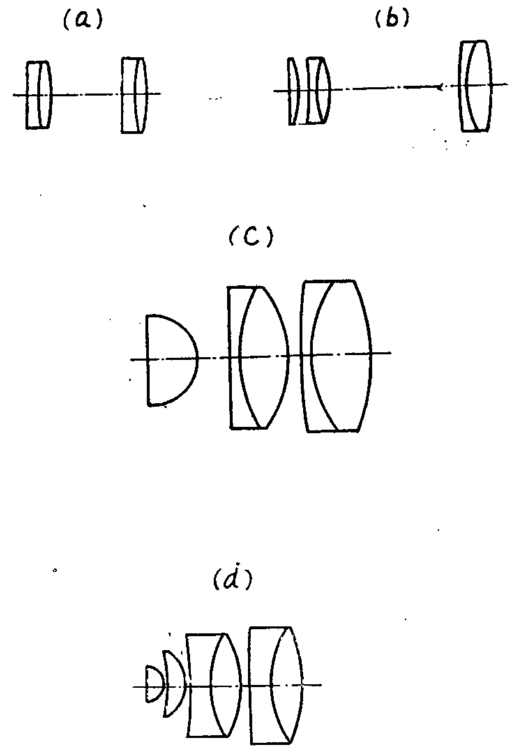

Fig. 9

Table 4. Summary of the Results of Examination
Part II. Objective

	Models	Large-sized			Medium-sized		
	Classes	1 st	2 nd	rest	1 st	2 nd	rest
Magnification	3∼5×	12	2	0	4	0	0
	10∼20×	25	9	0	6	0	0
	40×	29	2	1	6	0	0
	90∼100×	24	0	2	/	/	/
N.A.	10×	32	0	2	6	0	0
	40×	32	0	0	6	0	0
	Oil immersion	22	4	0	/	/	/
	Classes	A	B	C	A	B	C
Eccentricity	10×	21	10	3	5	1	0
	20×	0	1	1	/	/	/
	40×	22	10	2	6	0	0
	90∼100×	20	4	2	/	/	/

Note :- The figures represent the number of microscopes qualified as 1 st, 2 nd and the rest classes respectively as for each item.

(k) Eyepiece. The kinds of eyepieces placed at the disposal of the Committee were Huygenian, Periplanatic and Compensating eyepieces.

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The results are shown in Table 5.

Table 5. Results of Examination of Eyepieces

Models	Large-sized			Medium-sized		
Classes	1 st	2 nd	rest	1 st	2 nd	rest
5×	28	3	3	2	0	0
7∼8×	12	0	0	2	0	0
10∼12×	31	1	0	4	0	0
15∼20×	35	1	0	6	0	0

(l) Condenser. It was found by measurement that real numerical aperture was short of the nominal one. 5 out of 8 condensers of N.A. 1.4 and 4 out of 14 condensers of N.A. 1.2 were qualified as the 1st class. As far as the eccentricity is concerned, all condensers have come up to the standard.

(m) Total eccentricity. As a whole, total eccentricity error was very small and the result was excellent. 87% of microscopes submitted to examination was graded as A class.

(n) Parfocality. As the result of examinaton of dry objectives only, it was found that 8 sets out of 34 large-sized microscopes have the foci of their objectives fluctuated between ±0.02∼0.03 mm and 30 sets came up to the standard of A class. Measurement of change of focal planes of dry objectives and oil immersion showed that 22 sets were graded as A class.

(o) Definition. The examiners were of opinion that the achromats at their disposal were excellent in definition and they have come to rank with the best achromats of the world. It is regretable, however, that neither semi-apochromat nor apochromat were submitted to examination.

IV. Future of Microscope Industry in Japan

As was mentioned previously, the microscopes submitted to inspection are not all kinds of microscopes made in Japan, but in addition to same, we had immersion system, binocular microscope, polarization microscope, metallurgical photomicrograph already manufactured in the prewar times. Some of our optical companies have already undertaken to make all kinds of them as in the prewar times. And recently binocular microscopes have been made and exported to the United States.

On the other hand, the Government authorities adviced the private industrialists to investigate materials now in use with a view of replacing them by better ones; to find some way of improving both the grinding and polishing lenses; to make use of a microscope interferometer to test objectives; to pay attention to the advancement of ultra-violet microscope, catadioptric microscope and pancratic condensers, etc.

Japanese microscope industrialists are very much anxious to catch up with the level of the optical industry in the United States, Great Britain and Germany and to manufacture various kinds of microscopes which sustain comparison with those manufactured in the said countries. They are, however, still left in the tight-money situation and not in a position to conduct a business to the full extent. Yet none of them does not spare their efforts to organize themselves to meet their own problems. I am confident that microscope industry in Japan will flourish without fail. It is only a question of time.

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APPENDIX

TABLE I.

Methods of Testing and Standards for Classification

<table>
<tr><th>Items to be tested</th><th>Methods of Testing</th><th>Scope of Application</th><th>Standards for Classification</th></tr>
<tr><td>I. Exterior Appearance
1. Painting
Craftmanship
Scratches and others</td><td>
To examine first coat, mending paint, bubbles, spots, specks.
To examine scratches, peeled parts.</td><td>
All kinds of large-, medium- and small-sized models.</td><td rowspan="4">To be graded into three classes of A, B and C according to the following standards provided for each model :
<table><tr><th>Model / Class</th><th>Large-sized</th><th>Medium- and small-sized</th></tr><tr><td>A</td><td>85 or more</td><td>80 or more</td></tr><tr><td>B</td><td>60 or more</td><td>60 or more</td></tr><tr><td>C</td><td>less than 60</td><td>less than 60</td></tr></table>The figures denote percentage of points obtained.</td></tr>
<tr><td>2. Plating</td><td>To examine craftmanship of finish, scratches, rust, stain, decoloring, peeled parts.</td><td>ditto</td></tr>
<tr><td>3. Processing and Constructing
General items</td><td>To measure mechanical tube length with a nonius ; to examine dusts, balsam bubbles in the contact surface, scratches, incompletion of polishing, etc. of optical parts ; perfectness of screw heads, edging of stand, blow-holes in the casting, tightness of knobs ; distortion, convexity and stability of the stage and others.</td><td>ditto</td></tr>
<tr><td>Draw tube</td><td>To examine engraving, fitting in, dimension, scratches and others.</td><td>Those which have graduated tube</td></tr>
<tr><td>II. Dimension of Parts
1. Male screw of an objective</td><td>
To be tested with a limit gauge.</td><td>
Large-sized model and 1 st class goods of medium-sized.</td><td>
Too large one to be graded as C class ; too small but practically admissible one as B class.</td></tr>
<tr><td>2. Female screws of body tube and of revolving nosepiece</td><td>ditto</td><td>ditto</td><td>Too small one as C class ; too large but practically admissible one as B class.</td></tr>
<tr><td>3. Outer diameter of eyepiece</td><td>To be tested with a gauge</td><td>ditto</td><td>Too large one as C class ; too small but practically admissible one as B class.</td></tr>
<tr><td>4. Inner diameter of eyepiece sleeve</td><td>ditto</td><td>ditto</td><td>Too small one as C class ; too large but practically admissible one as B class.</td></tr>
</table>

Items to be tested	Methods of Testing	Scope of Application	Standards for Classification
5. Outer diameter and height of sub-stage	ditto (height of condenser is measured from the bottom to the top surface with a special tester made for this purpose. See Fig. 1 in the text.)	Those which have condensers.	Too large and too high one as C class ; too small and too low but practically admissible one as B class.
6. Substage sleeve Inner diameter	To be tested with a gauge.	ditto	Too small one to be graded as C class : too large but practically admissible one as B class.
Eccentricity	To be examined by using objective of 10x, standard eyepiece, substage and eccentricity tester (See Fig. 2 in the text)	ditto	That in which the image of the perforation of substage's eccentricity tester internally touches the circle of the field number 12 or less as A class ; that in which the said image internally touches the circle of the field number 14 or less as B class.
7. Inner diameter of clip-hole in the stage and spring of clip.	To examine clip-hole with a gauge and also strength of spring.	Large-sized model with respect to inner diam.; to all models with respect to spring.	That with too small inner diameter to be graded as C class ; that with too large but practically admissible inner diameter as B class.
III. Function of Mechanical Portion 1. Coarse adjustment Back-lash of rack and pinion	Peer through the microscope carrying an objective of the highest magnification at a test-specimen and then lower the objective down and raise it very slowly to find the position of the finest definition. And then gently press the body-tube upward and downward. Find the diminution in definition by this operation.	All kinds of large-, medium- and small-sized models.	That which still gives sharp image to be graded as A class ; in other cases, to be graded according to the degree of diminution in difinition.
Looseness of dovetail	Gently press the upper and lower portions of the body-tube carrying a highest power dry objective sidewise alternately.	ditto	In large-sized model, 0.01 mm or less to be graded as A class ; 0.01-0.015 mm as B class. In medium-sized model, 0.03mm

Items to be tested	Methods of Testing	Scope of Application	Standards for Classification
	And then measure the amount of the permanent deviation by the aid of 1/100 mm stage-micrometer.		or less as A class ; 0.03-0.045 mm as B class. In small-sized model, 0.06 mm or less as A class ; 0.06-0.09 mm as B class.
Tightness	To examine by operating the coarse adjustment when a high power dry objective is screwed on the body tube ; to carry out this test within 80 percent of its length without looking through the microscope.	ditto	To be graded taking into consideration of the condition in the place mostly used.
Fitting in of taper	To examine the fitting in after adjustment is over.	Those which are provided with taper	To be graded according to easiness of adjustment as well as its result.
2. Fine adjustment			
Back-lash	To measure by the aid of an indicator with graduation of 1/100 mm, scribing block and a dial having 1/200 graduation attachable to the fine adjustment knob when an immersion objective and a test-specimen are used.	Large-sized model	In the Mayer system, 2 μ or less to be graded as A class. 3 μ or less as B class; In the simple system, 4 μ or less as A class ; 6 μ or less as B class.
Looseness of dovetail	To examine in the same way as in the case of coarse adjustment.	ditto	Same as in the case of coarse adjustment.
Tightness	To examine by operating the fine adjustment when a dry objective of the highest magnification is screwed on the body tube; and also to carry out this test throughout their length without looking through the microscope.	ditto	Perfect one to be graded as A class ; others to be graded according to the conditions.
Index at both upper and lower limits	To be tested by naked eye.	ditto	That in which upper and lower lines perfectly coincide with the index as A class; that in which only one half breadth of either upper or lower lines coincide with the half breadth of the index as B class.

Items to be tested	Methods of Testing	Scope of Application	Standards for Classification
3. Revolving nosepiece Total eccentricity	Set an objective of 40× free from eccentricity and an eyepiece with a cross. Use a 1/100 mm section micrometer as an object. Revolve the nosepiece once from the right side and then from the left side. Take the difference of the readings. Repeat this operation for every perforation by screwing on the same objective every time.	All the microscopes carrying revolving nosepiece	In the large-sized model, 0.03 mm to be graded as A class and 0.05 mm as B class. In the medium-sized model, 0.05 mm as A class and 0.10 mm as B class.
Looseness of the axes	To take the maximum value of the reading after the revolver has been gently pressed. To take this reading for every perforation.	ditto	ditto
4. Stage Perpendicularity of the optical axis to the surface of the stage.	To measure with a stage perpendicularity tester and a thickness gauge. Medium-sized second class and small-sized models to be measured with a right angle gauge and a thickness gauge. (See Fig. 3 in the text.)	All types of large-, medium-ond small-sized models	In the large-sized model, 0.1 mm per 50 mm or less to be graded as A class and 0.3 mm per 50 mm or less as B class. In the medium-sized model, 0.2 mm per 50 mm or less as A class and 0.6 mm per 50 mm or less as B class. In the small-sized model, 0.3 mm per 50 mm or less as A class and 0.9 mm per 50 mm or less as B class.
Rotation	Use objective of 40×, standard eyepiece and a test-specimen. Turn the stage slowly operating the knob with finger and thumb and examine the deterioration of sharpness of image. Test also tightness, jump, backlash and stiffness of this mechanism.	Models which are provided with this function.	
Fine movement	To examine jump of image, diminution in definition, tightness and back-lash of screw, looseness of the spring by using an objective of 40× and a test-specimen.	ditto	

Items to be tested	Methods of Testing	Scope of Application	Standard for Classification
To and fro motion of the mechanical stage	To examine diminution in definition, tightness, looseness of dovetail insertion, back-lash, stiffness and jump of motion by using an objective of 40× and a test-specimen and as for those which have a graduation, to examine the accuracy of the vernier and its fixing.	ditto	
From side to side motion of the mechanical stage.	First of all to examine clips and then diminution in definition, back-lash, jump and stiffness by using an objective of 40× and a test-specimen ; as for those which have a graduation, to examine the accuracy of the vernier and its fixing.	ditto	
Stopper	To examine all the stoppers of both stage proper and mechanical stage. (See Figs. 4 and 5 in the text.)	ditto	
5. Illuminating apparatus			
Raising and lowering movement at right angle to the optical axis of substage	To examine tightness, looseness, back-lash, stiffness by operating knob with finger and thumb; eccentricity given rise to by this motion to be measured by eccentricity tester.	Models which are provided with this function	
Mirror	To examine performance and movement of mirror. Scratch of the surface, defects in silvering to be examined by naked eye.	All types of large-, medium- and small-sized models.	
Swing in and out of the iris diaphragm.	To examine eccentricity at its proper position and also to examine if it works well when either swing in or out.	Those which have Abbe illuminatiug apparatus	
Rotation	To examine stiffness, tightness and jump of the motion.	ditto	

Items to be tested	Methods of Testing	Scope of Application	Standards for Classification
Stopper of the guide screw	To examine behavior of guide and whether it stops in order or not.	ditto	
Spring of the sleeve	The spring must be strong enough to prevent the condenser to fall down when the stopper attached to the sleeve is made loose.	Those which have this function	
Behavior of diaphragm	To examine form and diameter of aperture by closing and opening diaphragm and also whether closing and opening are operated properly or not.	ditto	
Eccentricity of diaphragm	To examine the diaphragm at its least aperture looking through the condenser by using ano bjective of 3× and a standard eyepiece.	ditto	Eccentricity of 20% of the field to be graded as A class ; that of 40% as B class.
Difference of height between the surface of the stage and the top surface of condenser at its highest position.	This difference to be measured by the aid of thickness gauge.	ditto	In immersion condenser, 0–0.1 mm to be graded as A class and 0.1–0.3 mm as B glass. In other condensers, 0–0.5 mm as A class.
6. Inclination of the limb and stability of stand.	To examine tightness, jump of motion and behavior in its vertical position. To examine its stability in its most unstable position.	All kinds of large-, medium- and small-sized models.	
IV. Capability of Optical Parts.			
1. Objective. Magnifying power.	By using 1/100 mm stage micrometer and a micrometer eyepiece, take the ratio of the reading of the eyepiece micrometer to that of the object micrometer.	Large- and medium-sized models.	In the large-sized model, ± 5% to be graded as 1st class and ± 8% as 2nd class. In the medium-sized model, ± 7% as 1st class and ±12% as 2nd class.
Numerical aperture.	To be measured with an apertometer. Objectives of magnifying power of less than 10× were placed out of the scope of this measurement.	ditto	In the large-sized model, −4% to be graded as 1st class and −8% as 2nd class. In the medium-sized model, −8% as 1st class and −12% as 2nd class.

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<table>
<tr><th>Items to be tested</th><th>Methods of Testing</th><th>Scope of Application</th><th>Standards for Classification</th></tr>
<tr><td>Eccentricity of objective alone.</td><td>To be measured with an objective eccentricity measuring apparatus (Fig. 6) specially made for this purpose and an eyepiece with a cross using section micrometer as object.</td><td>Large-sized model and 1 st class goods of the medium-sized model.</td><td rowspan="2"><table>
<tr><th colspan="2">Type / Class</th><th>10× or more</th><th>20× or more</th><th>40× or more</th><th>Immersion</th></tr>
<tr><td rowspan="2">Large-sized</td><td>A class</td><td>0.04 mm</td><td>0.04 mm</td><td>0.035 mm</td><td>0.03 mm</td></tr>
<tr><td>B class</td><td>0.08</td><td>0.08</td><td>0.07</td><td>0.06</td></tr>
<tr><td rowspan="2">Medium-sized</td><td>A class</td><td>0.07</td><td>0.07</td><td>0.06</td><td>0.05</td></tr>
<tr><td>B class</td><td>0.14</td><td>0.14</td><td>0.12</td><td>0.10</td></tr>
</table></td></tr>
<tr><td>Performance.</td><td>To test whether the objective of 40-45× performs properly when a cover-glass of 0.4 mm in thickness is placed on the test-specimen. To examine immersion objective of its performance without putting oil on the test-specimen.</td><td>Large- and medium-sized models.</td></tr>
<tr><td>2. Total magnification of small-sized model.</td><td>To be measured by total magnification measuring apparatus(1) with 1/100 mm micrometer as object.</td><td>Small-sized model.</td><td>±20% to be graded as 1 st class and ±30% as 2nd class.</td></tr>
<tr><td>3. Eyepiece.
Magnifying power.</td><td>To measure the focal length f and calculate 250/f.</td><td>Large- and medium-sized model.</td><td>In the large-sized model, ±5% to be graded as 1 st class and ±8% as 2 nd class. In the medium-sized model, ±7% as 1 st class and ±12% as 2 nd class.</td></tr>
<tr><td>Field number.</td><td>To be measured by an objective, true magnifying power of which is known and 1/100 mm stage micrometer. Field number is found by multiplying the magnifying power of the objective by the reading of the object micrometer.</td><td>ditto</td><td>In the large-sized model, 135/(magnification+2) to be graded as 1 st class and 120/(magnification+2) as 2 nd class. In the medium-sized model, 125/(magnification+2) as 1 st class and 110/(magnification+2) as 2 nd class.</td></tr>
<tr><td>Eccentricity of field diaphragm.</td><td>Making use of a suitable objective and 1/100 mm stage micrometer, turn round the eyepiece to take readings of the field at various places. Thus find the eccentricity of the diaphragm and calculate its percentage.</td><td>All types of large-, medium- and small-sized models.</td><td>In the large-sized model, ±3% to be graded as A class and ±5% as B class. In the medium-sized model, ±5% as A class and ±7% as B class. In the small-sized model, ±7% as A class and ±9% as B class.</td></tr>
</table>

(1) This is such a small telescope as a dynameter, having a micrometer at the focus.

Items to be tested	Methods of Testing	Scope of Application	Standards for Classification
Front focus.	Use an objective of 10×. At first look through the lowest power eyepiece and change the eyepiece from the lowest to the highest power successively. Observe the field diaphragm and the image of the object and examine the definition spoiled if any.	Those which are provided with more than two eyepieces.	
4. Condenser. Numerical aperture.	Put a rectangular parallelopiped glass on the oiled top of the condenser and send parallel rays by a collimator (See Fig. 7 in the text.) The angle of cone of rays emerging from the condenser can be easily measured either by observation or by taking photograph sideways. (See Fig. 8 in the text.). Calculate $n \sin \theta/2$.	Large-sized model.	±0.1 to be graded as 1 st class and ±0.15 as 2 nd class.
Eccentricity.	Observe the image of an infinitely distant point formed by the condenser by the aid of an objective of 10 × and measure the diameter of the circle described by this image when the condenser is rotated.	ditto	0.1 mm to be graded as A class and 0.2 mm as B class.
V. Performance as a whole 1. Total eccentricity.	Make use of an eyepiece with cross and a stage section micrometer. Screw all the objectives into perforations of revolving nosepiece one after another. Bring an objective into the optical path once from the left side and next from the right and measure eccentricity. Apply the same operation to all other perforations. Plot the data on a section paper. Take the maximum value as "total eccentricity."	Those which are provided with revolving nosepiece.	0.06mm to be graded as A class and 0.09 mm as B class.

<table>
<tr><th>Items to be tested</th><th>Methods of Testing</th><th>Scope of Application</th><th>Standards for Classification</th></tr>
<tr><td>2. Parfocality.</td><td>Screw one and the same dry objective of 40× into every perforation of revolving nosepiece and measure the change of focal plane either with graduation attached to fine adjustment or an indicator. Next screw every dry objective into one and the same perforation and measure the change of focal plane. Add maximum values of both measures. To find discrepancy of foci between dry and immersion systems, find first the focus of dry system, say that of 40×, and then change the objective to immersion system and find the focus after having operated as immersion. Take the difference between these two.</td><td>ditto</td><td>For dry system, ±0.1 mm to be graded as A class and ±0.15 mm as B class. For immersion system, from −0.1 mm to −0.4 mm as A class and from −0.05 mm to −0.6 mm as B class.</td></tr>
<tr><td>3. Definition.</td><td>1. To examine resulting definition and curvature of field of cevery objective under the illumination of artificial light by using test-specimen and standard eyepiece.
(a) Test-specimen either of the first or of the second kind should be used in accordance with the objective under test. Now look through the instrument and adjust until the finest definition is obtained at the central portion of the field, and then measure the area of the fine and clear definition by the standard eyepiece.
(b) Next operate the fine adjustment so as to make the marginal portion to appear in excellent definition and measure the annular portion of fine definition. Calculate</td><td>All types of large-, medium- and small-sized models.</td><td><table>
<tr><td>Size</td><td></td><td colspan="2">3×, 4×</td><td colspan="2">10×</td><td colspan="2">20×</td><td colspan="2">40×</td><td colspan="2">im-mer-sion</td></tr>
<tr><td rowspan="3">Large-</td><td></td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td></tr>
<tr><td>center</td><td>60</td><td>50</td><td>50</td><td>45</td><td>40</td><td>35</td><td>35</td><td>30</td><td>30</td><td>25</td></tr>
<tr><td>margin</td><td>90</td><td>80</td><td>80</td><td>70</td><td>70</td><td>60</td><td>60</td><td>50</td><td>50</td><td>40</td></tr>
<tr><td rowspan="2">Medium-</td><td>center</td><td>55</td><td>45</td><td>45</td><td>40</td><td>35</td><td>30</td><td>30</td><td>25</td><td></td><td></td></tr>
<tr><td>margin</td><td>80</td><td>70</td><td>70</td><td>60</td><td>60</td><td>50</td><td>50</td><td>40</td><td></td><td></td></tr>
<tr><td>Class</td><td></td><td>A</td><td>B</td><td>A</td><td>B</td><td>A</td><td>B</td><td>A</td><td>B</td><td></td><td></td></tr>
</table>In small-sized model: those which clearly resolve into lines of the test-specimen of the 1st kind to be graded as A class and those which recognize them as B class.</td></tr>
</table>

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Items to be tested	Methods of Testing	Scope of Application	Standards for Classification
	its percentage to the total area. 2. Moreover, every examiner is recommended to test optical parts with Abbe test-plate, artificial star, diatom, bacillus or any other samples of fine structure to find the resolving power of the objective.		

Remark : In the above table, 1 st class and 2 nd class denote those stipulated in JES respectively. The grades which are not stipulated in JES are denoted by A class, B class and C class as defined in the table.

TABLE II

Chief Japanese Microscopes

1. Large-sized Microscopes

Trade Name	Type	Tube length	Objectives	Eyepieces	Magni-fication	Nose-piece	Stage	Body	Substage (Condenser N.A.)	Remark
ELIZA	EHS	170	10, 40, 100	5, 7, 10, 15	50–1500	3	SPaM	MD	S 1.2	
〃	EH	170	10, 40. 100	5, 7, 10, 15	50–1500	3	CR	MD	S 1.2	
〃	EF	160	4. 10, 60	5, 8, 15	20–900	3	CP	M	DL	
KINEI	KB	170	10, 40, 100	5, 10, 15	50–1500	3	CR	MD	S 1.2	
〃	KBS	170	10, 40, 100	5, 10, 15	50–1500	3	SPaM	MD	S 1.2	
〃	KC	160	4, 10, 60	5, 10, 15	20–900	3	SP	M	DL	
KYOWA	KO	170	4, 10, 40, 100	M5, 10, P15, K20	20–2000	4	CRM	MD	A 1.4	
〃	KH	170	4, 10, 40, 100	5, 10, P 15	20–1500	4	CR	MD	S 1.2	
〃	KHS	170	10, 40, 100	5, 10, P 15	50–1500	3	SPaM	MD	S 1.2	
〃	KC	170	10, 40, 100	5, 10, P 15	50–1500	3	CR	MD	S 1.2	
〃	KA	170	10, 40, 100	5, 10, P 15	50–1500	3	SP	M	S 1.2	
〃	KS	170	10, 40, 60	5, 10, 15	50–900	3	SP	M	D	
〃	K-P	170	10, 40, 100	5, 10, P 15	50–1500	3	SPaM	MD	S 1.2	Portable
MAGNA	E 3 N	170	5, 10, 40, 100	5, 10, 15, K 20 W.F7, W.F10	25–2000	4	RM	B	A 1.4	Monocular tube
〃	D 3 N	170	5, 10, 40, 100	5, 10, 15, K 20 W.F7, W.F10	25–2000	4	RM	MD	A 1.4	
〃	AIL	170	5, 10, 40	5, 10, 15	25–600	3	CP	M	D	
MAGNA	DIL	170	10, 40, 100	5, 10, 15	50–1500	2	SP	MD	S 1.2	Portable
NIPPON-KOGAKU	KUG	160	4, 10, 40, 100	5, 10, 15	20–1500	4	SM	MD	A 1.4	Binocular tube attachable
〃	KUD	160	4, 10, 40, 100	5, 10, 15	20–1500	4	CR	MD	A 1.4	〃
〃	KEG	160	4, 10, 40, 100	5, 10, 15	20–1500	4	SM	MD	S 1.2	〃
〃	KED	160	4, 10, 40, 100	5, 10, 15	20–1500	4	CR	MD	S 1.2	〃

Trade Name	Type	Tube length	Objectives	Eyepieces	Magni-fication	Nose-piese	Stage	Body	Substage (condenser N.A.)	Remark
OLYMPUS	UCE	160	4, 10, 40, 100	5, M7, 10, P15, 20	20–2000	4	CRM	MD	A 1.4	
〃	OA	160	4, 10, 40, 100	5, 10, P 15, K 20	20–2000	4	CR	MD	S 1.25	
〃	OB	160	4, 10, 40, 100	5, 10, P 15, K 20	20–2000	4	SM	MD	S 1.25	
〃	GC	160	10, 40, 100	5, 10, P 15	50–1500	3	CR	MD	S 1.2	
〃	GB	160	10, 40, 100	5, 10, P 15	50–1500	3	SPaM	MD	S 1.2	
〃	GK	160	10, 40, 100	5, 10, P 15	50–1500	3	CR	M	S 1.2	
〃	GHS	160	4, 10, 40	10, P 15	40–600	3	SP	M	D	
SEIKO	SA	170	4, 10, 40, 100	5, 8, 10, 15	20–1500	4	CRM	MD	A 1.4	
〃	SO	170	10, 40, 100	5, 10, 15	50–1500	3	CRM	MD	S 1.2	
〃	SK	170	10, 40, 100	5, 10, 15	50–1500	3	CR	MD	S 1.2	
〃	SIA	170	10, 40, 100	5, 10, 15	50–1500	3	SP	MD	S 1.2	
〃	SIB	170	10, 40, 60	5, 10, 15	50–900	3	SP	M	S 1.2	
SHIMADZU-KALNEW	SKA	170	4, 10, 40, 100	5, M8, 12, 15, K20	20–2000	4	SM	MD	A 1.4	
〃	SKB	170	4, 10, 40, 100	5, M8, 12, 15, K20	20–2000	4	CM	MD	A 1.4	
〃	SKM	170	10, 40, 100	5, 10, 15	50–1500	3	SPaM	MD	S 1.2	
〃	SKO	170	10, 40, 100	5, 10, 15	50–1500	3	SR	MD	S 1.2	
TIYODA	Lbi	160	10, 20, 40, 90	5, 7, 10, K15, K20	50–1800	4	CRM	B	A 1.4	Monocular tube. Dark ground condenser
〃	L	160	10, 20, 40, 90	5, 7, 10, K15, K20	50–1800	4	CRM	M	A 1.4	Dark ground condenser
〃	Abi	160	10, 20, 40, 90	5, 7, 10, K15, K20	50–1800	4	CRM	B	A 1.4	Monocular tube
〃	A	160	10, 20, 40, 90	5, 7, 10, K15, K20	50–1800	4	CRM	MD	A 1.4	
〃	B	160	3, 10, 40, 90	5, 7, 10, 15	15–1350	4	CR	MD	S 1.2	
〃	G	160	10, 20, 40, 90	5, 7, 10, 15	50–1350	4	SM	MD	S 1.2	
〃	Q	160	10, 40, 90	5, 10, 15	50–1350	4	SPaM	MD	S 1.2	Portable
UNION-(SUMP)	UB 4	170	10, 40, 100	P 5, P 10, K 15	50–1500	3	CR	MD	S 1.2	Projection
〃	B 4	170	10, 40, 100	P 5, P 10, K 15	50–1500	3	CR	MD	S 1.2	Projection
〃	UK	170	10, 40, 100	5, 8, 15	50–1500	3	CR	MD	S 1.2	
〃	UG	170	4, 10, 40	5, 8, 15	20–600	3	SP	M	D	
〃	YA	170	4, 10, 40, 100	5, 8, 12, K 20	20–2000	4	CRM	MD	A 1.4	

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Trade Name	Type	Tube length	Objectives	Eyepieces	Magnification	Nosepiece	Stage	Body	Substage (condenser N.A.)	Remark
YASHIMA	BYD	170	4, 10, 40, 100	5, 8, 10, K 20	20-2000	4	SPaM	B	S 1.2	Monocular tube
〃	YDS	170	10, 40, 100	5, 8, 15	50-1500	3	SPaM	MD	S 1.2	
〃	YD	170	10, 40, 100	5, 8, 15	50-1500	3	CR	MD	S 1.2	
〃	YF	170	10, 60	5, 8, 12	50-720	2	SP	M	I	

2. Medium-sized Microscopes

Trade Name	Type	Tube length	Objectives	Eyepieces	Magnification	Nose-piece	Stage	Boby	Substage
ELIZA	ES	160	4, 10, 40	8, 15	32-600	3	CP	M	D
KINEI	KD	160	4, 10, 40	5, 8, 15	20-600	3	SP	M	D
KYOWA	KK	160	4, 10, 40	10, 15	40-600	3	SP	M	D
〃	HT	160	10, 40	10, 15	100-600	—	CP	M	D
OLYMPUS	ST	160	10, 40	10, P 15	100-600	—	CP	M	D
SHIMADZU-KALNEW	SKD	170	10, 40, 60	10, 12	100-720	3	SP	M	—
〃	SS-2	160	10, 40	10, 15	100-600	2	SP	M	—
UNION (SUMP)	UA	170	4, 10, 40	5, 8, 15	20-600	3	SP	M	D
〃	US	155	10, 40	5, 15	50-600	—	CP	M	—
YASHIMA	YJ	160	4, 10, 40	5, 10, 15	20-600	3	CP	M	I

3. Small-sized Microscopes

Trade Name	Type	Tube length	Magnification
ELIZA	EK	140	200
MAGNA	MAGNA 300	113,	150-300
NIPPON-SEIKO	ST	128	200
〃	ST	135	300
〃	LT	135	300
SHIMADZU-KALNEW	SS-300	120	50-300

4. Stereoscopic Microscopes

Trade Name	Type	Objectives	Eyepieces	Magnification
KYOWA	KB	2	5, 10, 15	10-30
MAGNA	GA	2, 4, 6, 10	5, 10, 15	10-150
OLYMPUS	XA	G 1, G3, G 6,	G 8, G 12, 5	8-75
SHIMADZU-KALNEW	SGA	G 2, G 4, G 6,	G 5, G 12	10-72
YASHIMA	YSA	1, 2, 3	8, 12, 15	8-45

5. Metallurgical Microscopes

Trade Name	Type	Tube length	Objectives	Eyepieces	Nose-piece	Stage	Body	Remark
YASHIMA	YMB	250	M1/12, M2, M3, M5,	5, 8, 10, 12, 15, P 10, K 12	4	SPM	M	Le Chatelier type, horizontal camera
OLYMPUS	MC	200	M 6, M 11, M 40, M 115	5, 10, CP 15	4	SPaM	MD	Camera attachable

6. Polarizing Microscopes

Trade Name	Type	Tube length	Objectives	Eyepieces	Stage	Body	Remark
NIPPON KOGAKU	POB	160	4, 10, 40	5, 7, 10	CR	M	Nosepiece, Condenser N. A 1.0
SHIMADZU-KALNEW	SPM	170	10, 40	5, 10	CR	M	Objective changer

7. Phase-Contrast Microscopes

Trade Name	Type	Tube length	Objectives	Eyepieces	Magni-fication	Nose-piece	Stage	Body	Substage	Remark
ELIZA	EHP	160	10, 40. 100	5, 7, 10, 15	50-1500	3	CR	MD	S 1.2	
〃	EFP	160	4, 10, 60	5, 8, 15	20-900	3	CP	M	L	
OLYMPUS	UCE Bi-PA	—	Ph 10, Ph 20 Ph 40, Ph 100	5, 10, CP 15	50-1500	4	CRM	B	A 1.4	
〃	OA-PB	160	Ph 10, Ph 20 Ph 40, Ph 100	5. 10, CP 15	50-1500	4	CR	MD	S 1.2	
〃	MC-PB	200	PhM 6, PhM 11, PhM 40, PhM 115	5, 10, CP 15	30-1725	4	SPaM	MD		Metallurgical
TIYODA	P	160	10, 20, 40, 90	5, 7, 10, 15	50-1350	4	SM	MD	S 1.2	
YASHIMA	YPD	170	10, 40, 100	5, 8, 15	50-1500	3	CR	MD	S 1.2	

Note :

Objective : G... Greenough, Ph... Phase, M... Metallurgical.
Eyepiece : M... Micrometer, P... Periplanatic, K... Compensating, W.F.... Wide field, C... Coated.
Stage : S... Square, C... Circular, P... Plain, R... Revolving, M... Mechanical, aM... attachable Mechanical.
Body : M... Monocular, B... Binocular, D... Draw tube.
Substage : S... Simplified illuminating apparatus, A... Abbe illuminating apparatus,
D... Revolving disc diaphragm, I... Iris diaphragm, L... Single lens condenser.

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TABLE III

Leading Microscope Makers in Japan

Name of Makers	Trade Names	Location.
Toyo Optical Co.	ELIZA	1168, Sasazuka-cho, Shibuya-ku, Tokyo
Kalnew Optical Co.	KALNEW	1, 3-chome, Moto-machi, Bunkyo-ku, Tokyo
Kinei Optical Co.	KINEI	325, 3-chome, Mabashi, Suginami-ku, Tokyo
Kyowa Optical Co.	KYOWA	516, Honan-cho, Suginami-ku, Tokyo
Tokyo Optical Co.	MAGNA	180, Motohasunuma-cho, Itabashi-ku, Tokyo
Japan Optical Co.	NIPPON-KOGAKU	5447, Oimorimae-cho, Shinagawa-ku, Tokyo
Nippon Seiko Co.	NIPPON-SEIKO	100, 1-chome, Nozawa-cho, Setagaya-ku, Tokyo
Olympus Optical Co.	OLYMPUS	9, Tagoto-cho, Shibuya-ku, Tokyo
Seiko Optical Co.	SEIKO	16, Yashima-cho, Nakano-ku, Tokyo
Shimadzu Works	SHIMADZU	Nijo-minami, Kawaramachi-dori, Kyoto
Tiyoda Optical Co.	TIYODA	531, Mure, Mitaka-shi, Tokyo
Union Optical Co.	UNION	15, 2-chome, Shimura, Itabashi-ku, Tokyo
Yashima Optical Co.	YASHIMA	470, Honan-cho, Suginami-ku, Tokyo

機械試驗所歐文報告

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GOVERNMENT MECHANICAL LABORATORY

BULLETIN

1954 No. 1

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By

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Ultrasonic Attenuation in Polycrystalline Steel

By *Akira Hikata*

I. Introduction

Recently a few investigators[1)2)3)4)5)6)7)8)9)10)] have developed the methods for searching properties of solid materials by ultrasonic pulses, and considerable information have been already obtained. This paper shows how the atttenuation of ultrasonic waves in steels changes when the specimens are magnetized or stressed.

II. Apparatus and materials

The block diagram of the method for measuring attenuation changes is shown in Fig. 1 and Fig. 2. A variable-frequency oscillator is the source of the carrier frequency. The firing of the pulses is controlled by a sinusoidal wave whose frequency is 50 cycles, and this timing wave also controls the sweep circuit of the cathode-ray oscilloscope. The time duration of each pulse is about 10 microseconds. The diameter of X-cut quartz crystal is 15 millimeters. The frequency of ultrasonic waves used in the present investigation is 5 megacycles only. All these apparatus were made in Japan Radio Company.

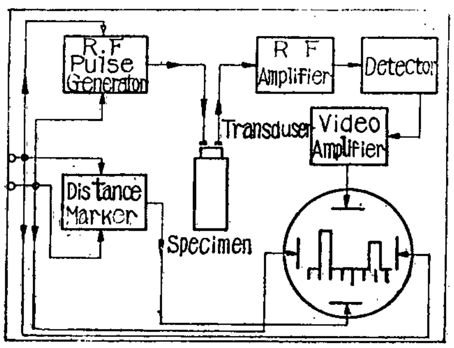

Fig. 1 Block Diagram of Ultrasonic Flaw Detector

The testing machine for applying tension to specimens is the usual universal material testing machine whose capacity is 50 tons. The capacity of testing machine for torsion is 100 kilogram-meters. The coil for magnetizing specimens, whose inner and outer diameters are 57 millimeters and 97 millimeters respectively, has a coil constant of 50 ampere-turns per centimeter. The materials used in this investigation

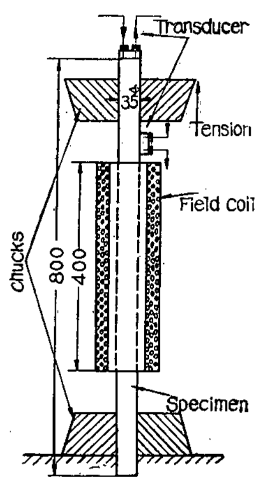

Fig. 2 Tension Test Apparatus

Table 1

	Chemical Composition %						Heat Treatment
	C	Si	Mn	P	S	Fe	
M_1	0.17	0.13	0.41	0.008	0.040	bal.	annealed at 600°C 1 hr
M_2	0.10	0.05	0.47	0.076	0.035	bal.	annealed at 600°C 3 hr
M_3	0.15	0.12	0.30	0.015	0.016	bal.	annealed at 600°C 3 hr
M_4	0.32	0.21	0.35	0.011	0.013	bal.	annealed at 800°C 3 hr
M_5	0.13	0.14	0.38	0.014	0.023	bal.	annealed at 800°C 3 hr
M_6	0.15	0.22	0.36	0.024	0.038	bal.	annealed at 600°C 3 hr
M_7	Cu ; 99.6 %						anneeled at 450°C 3 hr

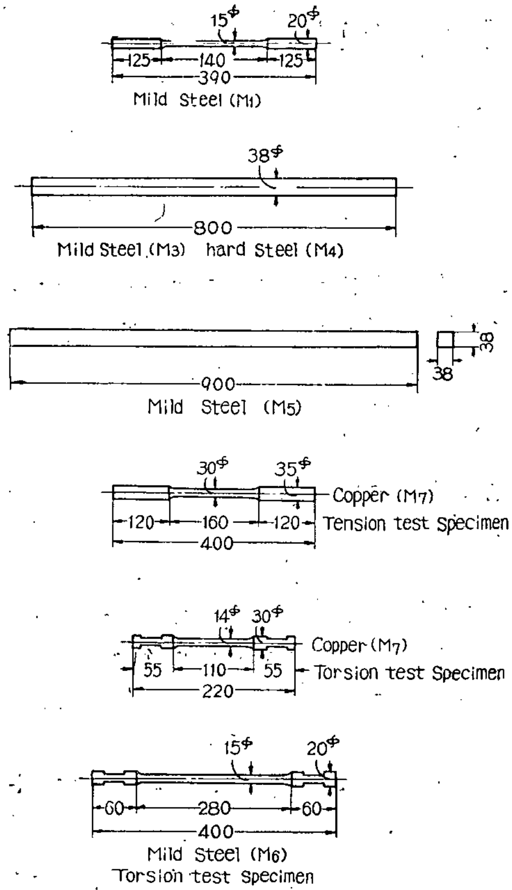

Fig. 3 Types of Specimens

are listed in Table I. Various types of specimens are shown in Fig. 3.

III. Experimental results

In the propagation of sound waves, it is generally considered that in multiple-reflections the relation between the ratio of sound pressure appearing successively in one end of the specimen and attenuation constant α is given as follows;

$$I = I_0 e^{-2mL\alpha}$$

$$I' = I_0 e^{-2mL(\alpha-\Delta\alpha)}$$

hence, the change of the attenuation α, denoted by $\Delta\alpha$, is determined by the next equation,

$$\Delta\alpha = \frac{1}{2mL} \cdot 20 \cdot \log_{10} \frac{I'}{I} \quad \text{db/cm},$$

where

L is the length of specimen in centimeter,

I is the amplitude of the m th echo at initial state, i.e., at zero magnetization o stress free state. I' is the amplitude of the same echo under magnetized or stressed state.

(1) Effect of Magnetic Field

It is already known that the internal friction of well annealed ferromagnetic materials may be greatly decreased by placing the material in a strong magnetic field which holds the domains firmly in a given orientation. As indicated in Fig. 4 for mild steel and Fig. 5 for hard steel, (where $\Delta\alpha$ is defined to be positive when attenuation α becomes smaller than initial state) the attenuation α decreases with increasing longitudinal magnetic field strength H. At the same time the changes of magnetic

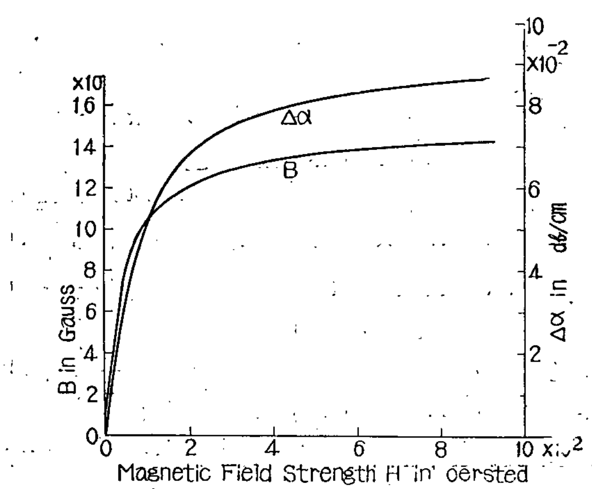

Fig. 4 Attenuation Changes of Mild Steel (M_3)

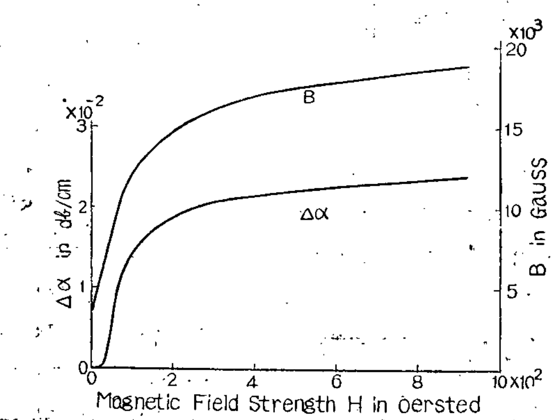

Fig. 5 Attenuation Changes of Hard Steel (M_4)

flux B are measured in the middle of the specimens. Both B and $\Delta\alpha$ curves have the same characteristics for the magnetic field.

(2) Effect of Stress

It is also well known fact that when a ferromagnetic body is stressed, the domains usually change their orientation. Therefore it is expected that if the specimen is stressed by tension, the attenuation may decrease for the same reason in the case (1). Fig. 6 for mild steel and Fig. 7 for hard steel show the effect of stress applied by simple tension. In mild steel the attenuation decreases with increasing stress up to the proportional limit, and then increases abruptly after reaching the yielding point. During the yielding process the height of the received pulses on cathode-ray oscilloscope rise and fall as the stress does.

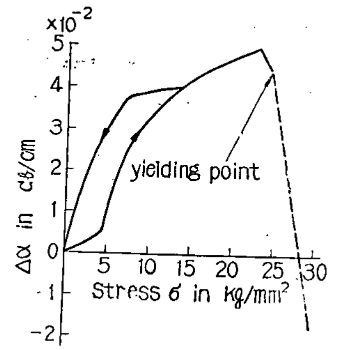

Fig. 6 Attenuation Changes of Mild Steel (M_3) in Tension

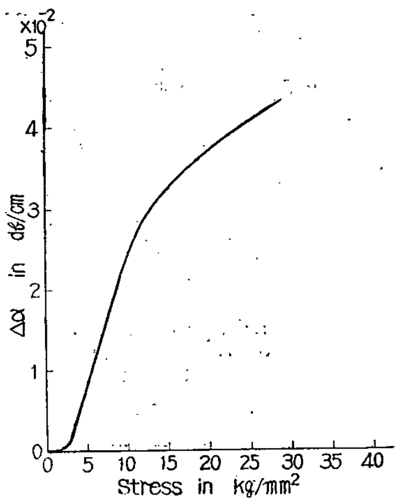

Fig. 7 Attenuation Changes of Hard Steel (M_4) in Tension

Since the increase in length of the specimen by tension are remarkable after reaching its yielding stress, it seems that the measured values of $\Delta\alpha$ in that range are not exact and too small compared to their true values. After correcting this change of dimension, however, there still exists a remarkable change in attenuation near the yielding stress and this abrupt change perhaps means the increase of internal friction caused by plastic deformation. To ascertain this, copper was also tested. Fig. 8 shows the attenuation changes in polycrystalline copper rod. The attenuation increases from the start as stress increases.

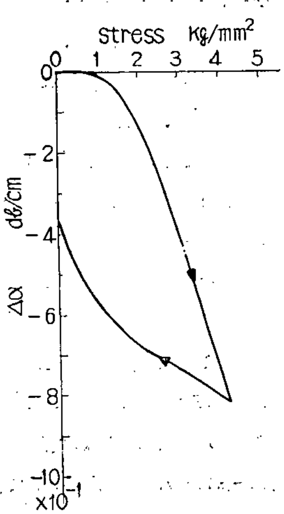

Fig. 8 Attenuation Changes of Copper in Tension

To eliminate the changes of dimension owing to tension load, torsion tests were performed. In this case, however, the stress distribution over the cross section is not uniform, i.e. even when the outer part of the specimen reaches its yielding stress, the stress of the inner part near its center axis remains still below the yielding stress. Therefore the abrupt changes of attenuation at yielding stree as appeared in tension test may not be expected in torsion test. Fig. 9 shows the attenuation changes of mild steel in torsion test. The attenuation decreases with increasing shearing stress up to a certain stress somewhat larger than its yielding stress and then tends to increase. In copper, as shown in Fig. 10,

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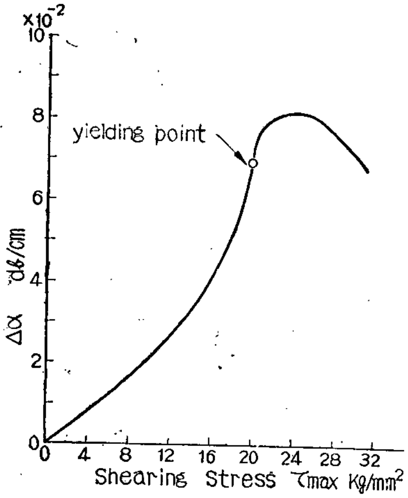

Fig. 9 Attenuation Changes of Mild Steel (M_6) in Torsion

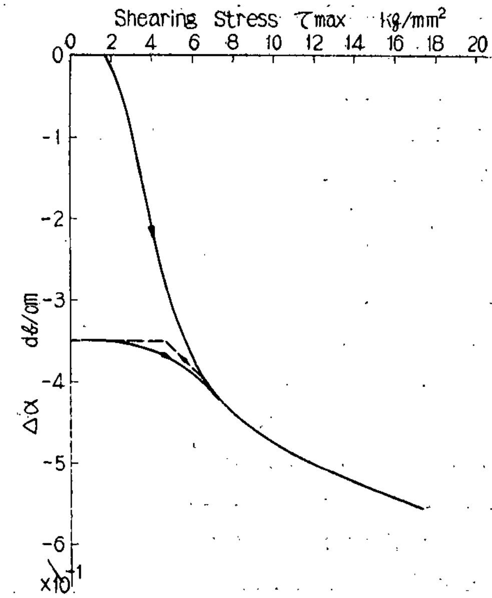

Fig. 10 Attenuation Changes of Copper in Torsion

the attenuation increases from the start as torsional shearing stress incneases.

So called "Hysteresis loops" was obtained also in ultrasonic attenuation as shown in Fig. 6. It may be seen that the attenuation at a given stress is lower just after the specimen has been stressed at a greater stress than it was previously. This irreversible properties of ultrasonic attenuation in steel was observed also in the course of experiments of magnetization.

As mensioned above the specimens subjected to large plastic deformation show large attenuation losses immediately after the deformation. By resting the specimens in unloaded state, however, the attenuation decreases with increasing time. It is considered this may be the phenomenon based on the so-called "Elastic after effect"

(3) Effect of Cold Work

Changes of attenuation induced by magnetic field of specimen stressed beyond its yielding point are shown in Fig. 11. In this case attenuation initially increases and then tends to decrease with increasing field strength H. This phenomenon is not observed in annealed steels and may be a subject full of interest.

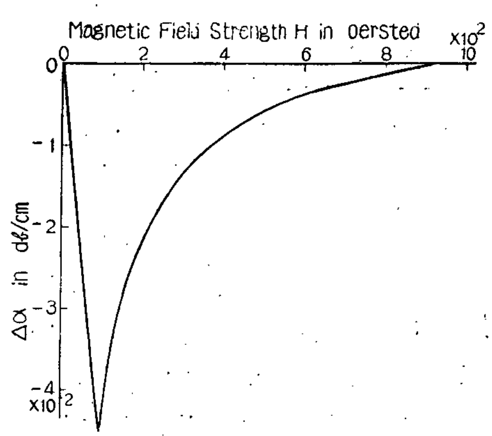

Fig. 11. Attenuation Changes of Mild Steel (M_3) after Plastic Deformation.

(4) Effect of Stress uder Magnetic Field

It is an interesting problem to examine the ferromagnetic materials subjecting to both stress and magnetization. To study this problem two experiments were performed. Fig. 12 and Fig. 13 are the results.

In Fig. 12, the upper curve indicates the changes of attenuation due to stressing only, while the lower curve is for the changes of attenuation of the same material due to tension under magnetic field whose strength H is 950 oersted, that is almost in saturation.

In the case of Fig. 13, in contrast with the case of Fig. 12, the specimen was held in a fixed stress, say 14 kg/mm², 21 kg/mm² or 28 kg/mm², and the magnetic field was changed. In both cases the results were as expected.

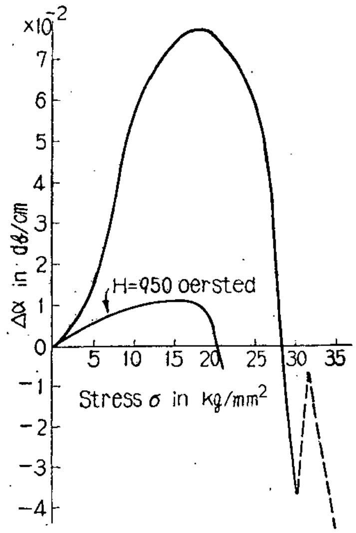

Fig. 12 Attenuation Changes of Mild Steel (M_3) by Tension Under Magnetic Field

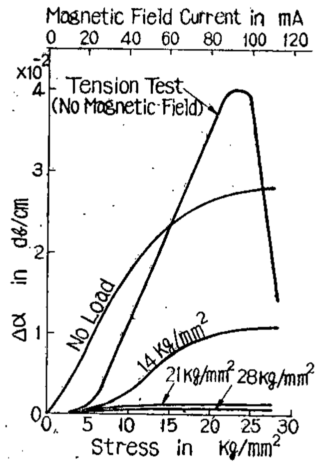

Fig. 13 Attenuation Changes of Mild Steel (M_1) by Magnetic Field Under Tension

(5) Esect of the Direction of Incident Wave

In all experiments described above, the ultrasonic waves are sent through the rod longitudinally. To compare the change of attenuation of ultrasonic waves sent through longitudinally with when they are transversely to the rod, a steel bar of squere cross section was employed. As shown in Fig. 14, there seems to be no difference in both

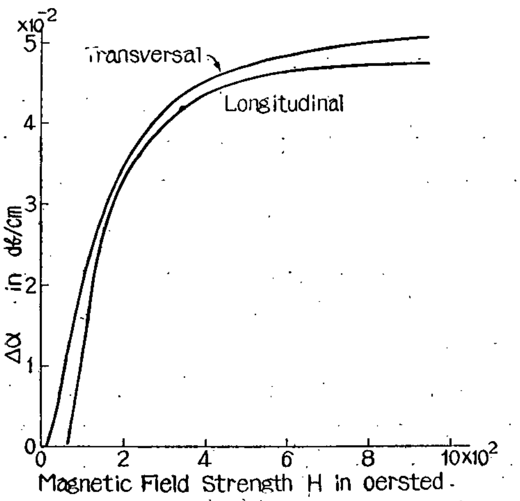

Fig. 14 Attenuation Changes of Mild Steel ; (M_5) Effect of the Direction of Magnetic Field

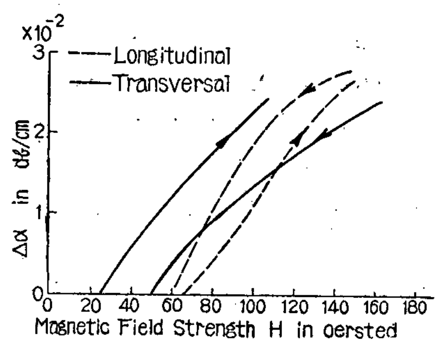

Fig. 15 Attenuation Changes of Mild Sieel ; (M_5) Effect of the Direction of Magnetic Field.

cases. According to the closer observation, however, a difference was found that in the former case attenuation at a given field strength is smaller just after the specimen has been magnetized at a greater field strengh than it was previously, while in the latter case it appears reversely as shown in Fig. 15.

IV. Summary

Changes of ultrasonic attenuation of metals subjecting various stresses are described. It is a subject of discussion what these attenuation changes investigated in this work would mean. As indicated by W. P. Mason, when high frequency longitudinal sound waves are sent through a multicrystalline rod of metal, attenuation losses result because of internal friction of the metal, scattering and diffusion of sound waves by the grains.

It is remarkable that when the grain size is about equal to or somewhat smaller than comparing to the wave-length, the scattering losses proportional to the fourth power of the frequency and diffusion losses inversely proportional to the grain diameter, but when the grain size is far smaller than the wave-length, the most part of the losses are due to the internal friction of the metal and become proportional to the frequency. The frequency used in the present investigation is 5 megacycles and the materials tested are steels in which the velocity of sound is about 5×10^5 cm/sec, so the wave-length becomes 1 mm approximately. As the grain size of the steels is in order of 10^{-2} mm or 10^{-3} mm, the wave-length is far larger than the grain size. In such a case as indicated by S. Tanaka[6], the scattering and diffusion losses become negligibly small and the attenuation losses may be caused by internal friction only. The attenuation constant $\alpha=A\cdot f$ (where A is a constant and f is a frequency) is the loss per centimeter of the metal, while internal friction is usually defined by the relration

$$\Delta=\frac{\Delta W}{W}$$

where ΔW is the energy dissipated per cycle and W is the total vibrational energy. Converting the unit of α from db/cm into loss per cycle,

$$\delta=\frac{1}{8.68}A\cdot f\cdot\frac{1}{\frac{1}{\lambda}}=A_0 V,$$

where λ is the wave-length, V is the velocity of sound in the metal and A_0 is a constant. This δ is obviosly indepedent of frequency.

Now, there are various types of loss mechanisms that have been observed to cause internal friction in solids such as thermoelastic relaxation, viscoelastic behavior, static hysteris; in ferromagnetic materials, magnetic hysteresis, micro and macro eddy current and so on. It is considered that the losses produced by thermal relaxation or viscoelastic behavior are too small to account for the losses measured in the high frequency range. A. S. Nowick[11][12] pointed out that for amplitude dependent and frequency independent internal friction, static hysteresis resulted from atomic as well as magnetic re-arrangements plays an important role. This kind of losses may be regarded as arising from the motion of dislocations. It is reasonable to consider that when a sound wave runs into a dislocation both may be disturbed. But the relationship between sound wave and disloction is still unknown and is the subject that should be solved by further investigations.

Acknowledgment

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BULLETIN

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No. 2

THE SIZE EFFECT IN FATIGUE OF NOTCHED STEEL SPECIMENS LOADED UNDER REVERSED DIRECT STRESS

By

Akira Hikata

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The Size Effect in Fatigue of Notched Steel Specimens Loaded under Reversed Direct Stress

By *Akira Hikata*

I. Introduction

It is well known that, under a repeated load, test specimens or machine parts with large cross-sections fail under lower computed stresses than those with smaller cross-sections do. This size effect in fatigue was of considerable importance in the heavy industries where large forgings, with their inevitable stress concentrations, had to be relied upon to transmit power under a variety of difficult conditions.

The literatures of the subject were full of informations on the fatigue properties of various materials, with and without stress concentrations, as determined by small specimens of 1/2 inch diameter or so, but the translation of those informations into the full scale had been rendered difficult by virtue of the so-called size effect which might vary from one material to another.

To test specimens with large cross-sections, previous works on fatigue concerning the size effect has generally been confined to testing undere bending conditions. Therefore, the stress gradient thereby imposed on the specimen has introduced a complicating factor into the analysis of the results. With notched specimens in bending, the stress gradient in the critical region is not only a function of the form of the notch, but also of the stress gradient introduced by the bending moment, which in turn depends on the diameter of the specimens.

This paper describes the work carried out in direct stress machines; the stress gradient across sections of specimens due to bending were thus avoided.

II. Material Tested

Table 1. Chemical Composition ; %

	Carbon	Silicon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	Copper
Mild Steel	0.28	0.26	0.47	0.037	0.027	0.10	—	0.34

The material used for the investigation is mild steel of 53 kg/mm² in ultimate tensile strength. This mild steel was supplied in one batches and in the form of bars 75 mm in diameter.

The chemical composition and mechanical properties of the mild steel are given in Table 1 and Table 2 respectively.

Table 2. Mechanical Properties

Yield Strength kg/mm²	30.5
Tensile Strength kg/mm²	53.1
Elongation %	34%
Vickers Hardness Number Hv	148

III. Testing Machine

The following two direct-stress fatigue mechines were available for the investigation:

20-ton Schenck Pulsator (2,900 cycles/min.)

1,5-ton Haigh Type Fatigue Machine (2,500 cycles/min.)

The Schenck Pulsator, Fig. 1 (a), is based on an oscillating mass spring principle, and is excited at just below the resonant frequency by a rotating unbalance mass, driven through a flexible drive by a variable-speed D.C. motor.

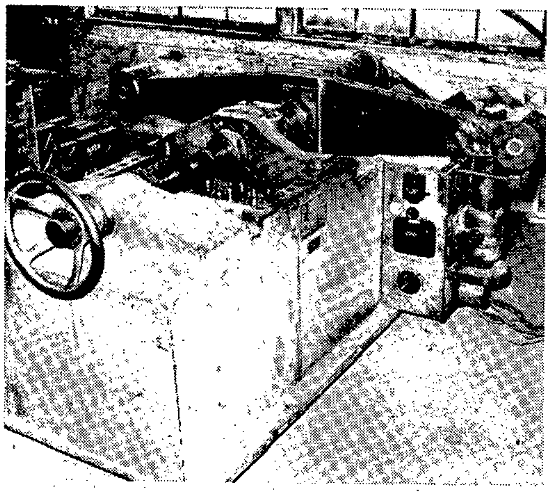


Fig. 1 (a) Schenck Pulsator

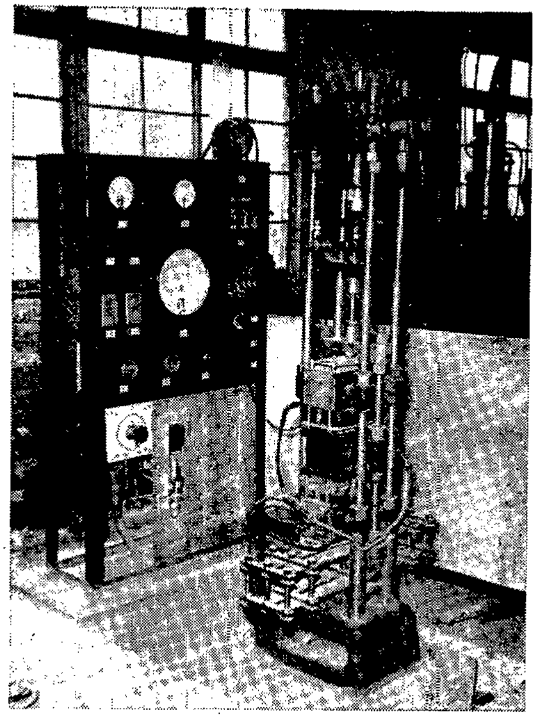


Fig. 1 (b) Haigh Type Machine

The stated capacity of the machine is, in the commonly accepted notation, ±10±10 tons. In carrying out the fatigue tests, a small static tension was applied to each test piece to reduce damage on the fracture surfaces of the piece at failure.

In order to measure the exact load during the tests, a loop dynamometer previously calibrated was newly attached to the Haigh Type Machine, as in the Schenck Pulsator.

The figure quoted in the tables of results is the semi range of stress applied.

IV. Specimens

The form of the plain test pieces is shown in Fig. 2.

The nominal proportions of the notched section of the specimens which are geometrically similar but of different size are shown in Fig. 3. The notch in each notched specimen was a hyperbolic groove with a root radius equal to 0,05 times the minimum diameter of the specimen.

According to the Neuber's[1)] formula, the value of the theoretical stress concentration factor (or form factor) α at the root of the groove of the proportions common to all notched specimens was found to be 4.68. This theoretical stress concentration factor α is the ratio σ_{max}/σ, in which σ_{max} denotes the maximum longitudinal stress at the root of the notch (as calculated by Neuber), and σ denotes the nominal longitudinal

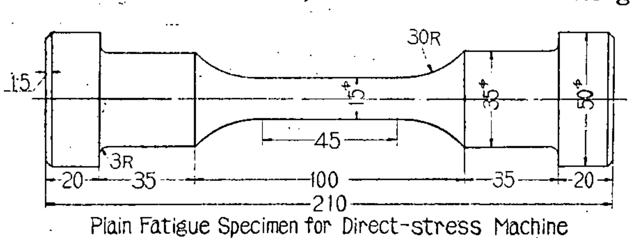
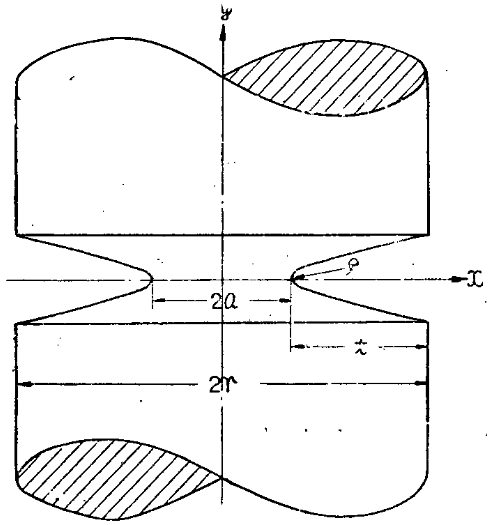


Fig. 2 Unnotched Specimen

stress as computed by the ordinary formula $P/\pi a^2$.



$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

Type specimen	No. 1	No. 2	No. 3	No. 4
a	3	6	10	17
ρ	0.15	0.3	0.5	0.85
t	6	12	20	19
r	9	18	30	36
b	0.671	1.342	2.236	3.801

Fig. 3 hyperbolic groove

The range of test-piece size and shapes are shown in Fig. 4 and Fig. 5.

V. Preparation of Test Piece

The usual care was taken in the preparation of test pieces; after a final light cut of a hundredth of a millimeter deep, the test piece was polished with No. 00 emery paper whilst being rotated slowly on a lathe.

Measurements of the average surface roughness of sample test pieces gave figures ranging from 2 to 4 microns, when the probe was moved in a longitudinal direction.

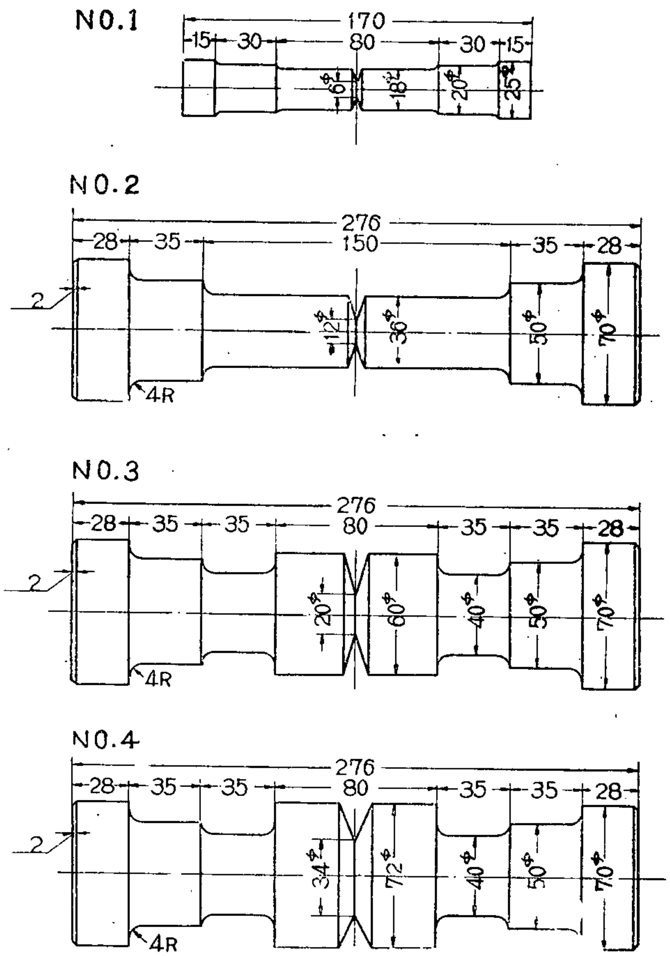


Fig. 4 Notched Specimen

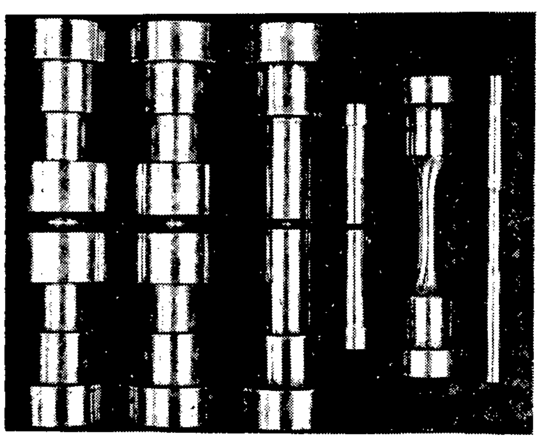


Fig. 5

The specimens containing hyperbolic grooves were made with a forming tool. The root radius was subsequently polished with No. 00 emery paper folded around a wire and lightly pressed into the groove whilst the speci-

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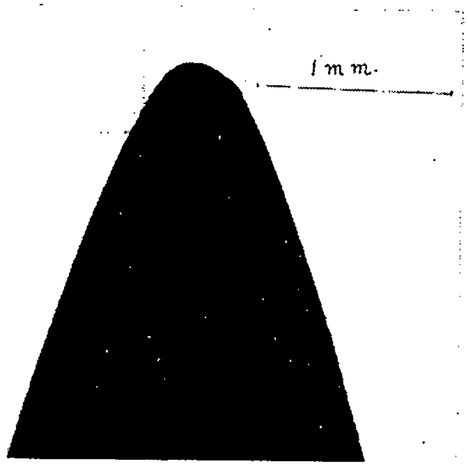
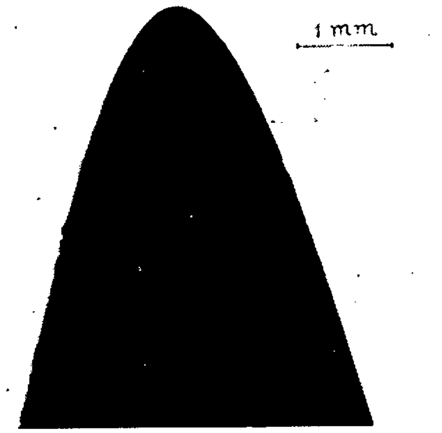


No. 1



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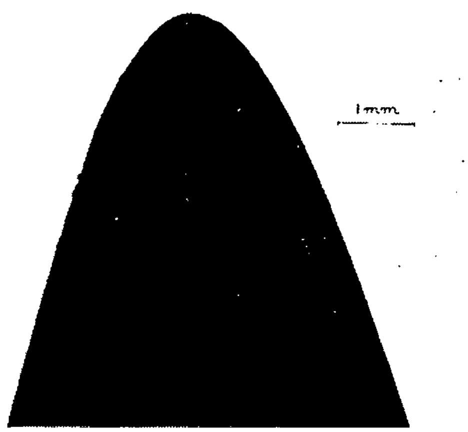

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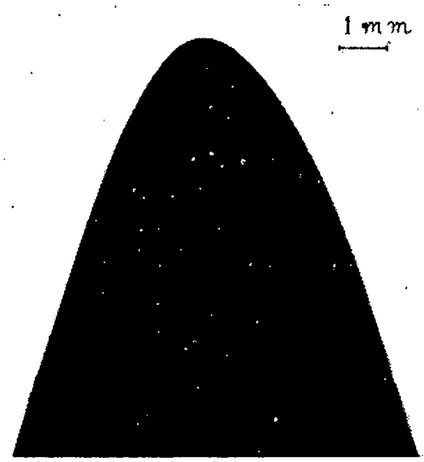

No. 4

Fig. 6

men being rotated on a lathe. The dimensions of the groove were finally checked by the projection method, and found to be reasonably consistent. No significant differences were found when individual root radii were compared with the results obtained. The photographs of the grooves from sample test pieces are shown in Fig. 6.

As failure all notched specimens were machined centrally from the bar, invariably started from the surface. But no segregation of sulphur was found by means of sulphur prints over the cross-section of the bars and also no flaw was detected by the inspection of ultrasonics of 5 mega-cycles. Fluctuation in properties throughout the thickness of the bars used for the test was checked by hardness explorations across a diametral section of each bar. Fluctuation in hardness was small, about 3~4 per cent, as shown in Fig. 7.

The heat treatment of the specimens was as follows ; before machining the material was normalized at 930°C for three hours. After machining and polishing the specimens were annealed at 400°C in a vacuum furnace so that the polished surfaces remained bright. Thus all residual stresses due to previous rolling, machining and polishing presumably were removed.

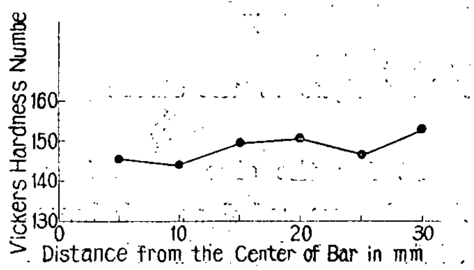

Fig. 7

Table 3.

	diameter d in mm	form factor α	fatigue limist kg/mm²	notch factor β
No. 1	6	4.68	10.5	2.2
No. 2	12	4.68	7.8	2.9
No. 3	20	4.68	7.0	3.3
No. 4	34	4.68	6.0	3.8

VI. Experimental Results and Discussion

The results of the fatigue tests are shown plotted in S-log N form in Fig. 8. Estimates of the fatigue limits are given in Table 3. The fatigue stress concentration factors (or notch factor) β are also summarized in Table 3. The notch factor or fatigue stress concentration factor is derived from the ratio of the fatigue limit of an unnotched specimen to that of the notched specimen, the fatigue limit being based upon minimum cross-sectional areas.

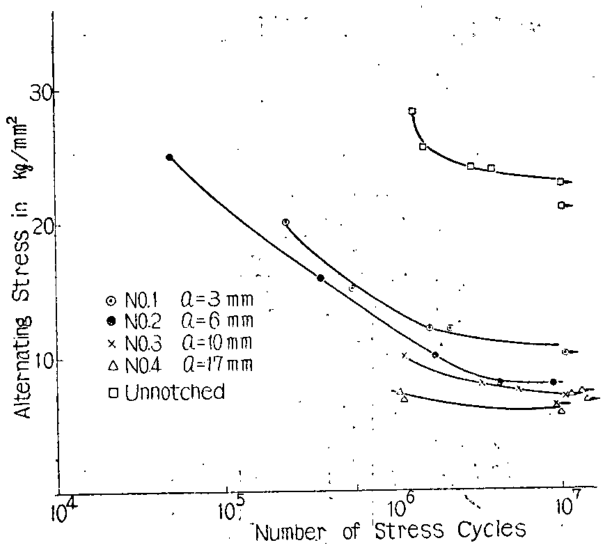

Fig. 8

Owing to restrictions in capacity of the testing machines used in the present research, the S-log N diagram for the largest specimens, Type No. 4, could not be entirely covered.

C. E. Phillips and R. B. Heywood[2)] indicated that the fatigue strength of unnotched specimens of mild steel was independent of the size of the test piece for diameter of the test section ranging from 0.19 inch to 1.3 inches when tested under reversed direct stress. So in the present reserach the fatigue limit of unnotched specimens was determined by specimens of 15 millimeter diameter only.

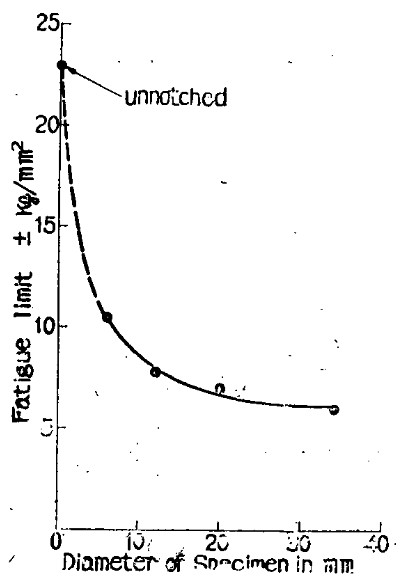

Fig. 9

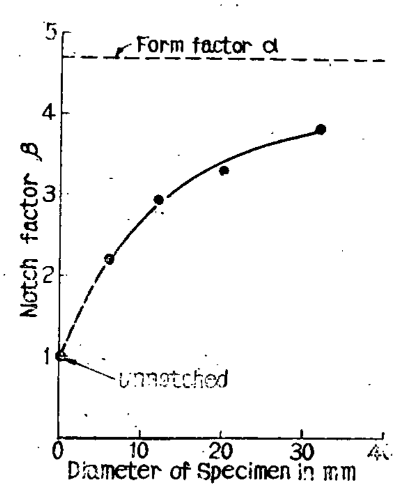

Fig. 10

Values of the fatigue limit and the notch factors for various sizes of specimen are plotted in Fig. 9 and Fig. 10 respectively, and indicate a general trend of the size effect that is to be expected.

The most popular theory to explain the size effect in fatigue is the stress gradient theory.

H. F. Moore[3] proposed the following hypothesis that for the size effect in plain specimens a fatigue specimen which fails under cycles of reversed flexure behaves as if a fatigue crack started slightly below the surface of the specimen, where the nominal stress is slightly lower than that at the surface, and further hypothesis that at this point below the surface the nominal stress at failure is independent of the size of the specimen, and the depth of this point from the surface is also independent of the size of the specimen.

For notched specimens T. Isibasi[4] suggested that the fatigue strength of notched specimens, in which the stress distribution is not uniform, must be determined not only by the stress at the tip of the notch, but also by the stresses in a certain finite region surrounding the root of the notch. In other words, this hypothesis may be said in such a way that the critical factor is the stress at point B slightly apart from the tip of the notch, say ε, in the direction along which the stress gradient is maximum. (See Fig. 11.)

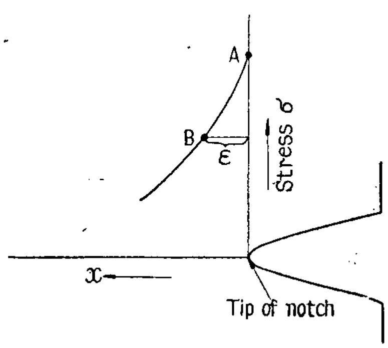

Fig. 11

When notch is not so sharp, it is reasonable to consider that the stress at point B may be equal to the fatigue limit of the plain specimen under a reversed direct load. Under this consideration, values of ε were computed as follows:

At first, the stress distributions in minimum cross-section were calculated by Neuber's formula using ellipsoidal-coordinate. Put

$$x=\sinh u\cdot\cos v,$$
$$y=\cosh u\cdot\sin v\cdot\cos w,$$
$$z=\cosh u\cdot\sin v\cdot\sin w,$$

then the nominal stress σ_u, σ_v, σ_w are obtained as follows;

$$\sigma_u=\frac{1}{h^2}\left[A\cdot\tanh^2 u+B\cdot\frac{\cos v}{\cosh^2 u}+C\cdot\left\{-2-\alpha+\frac{1}{\cosh^2 u}\right\}\cos v\right]+\frac{\cos v}{h^4}\left\{-A+B+C\cdot\cos^2 v\right\},$$

$$\sigma_v=\frac{1}{h^2}\left\{-A\frac{\cos v}{1+\cos v}+(\alpha-1)\cdot C\cdot\cos v\right\}+\frac{\cos v}{h^2}\left\{A-B-C\cdot\cos^2 v\right\},$$

$$\sigma_w=\frac{1}{h^2}\left[A\left(-\tanh^2 u+\frac{\cos v}{1+\cos v}\right)-B\cdot\frac{\cos v}{\cosh^2 u}+C\left(\alpha-1-\frac{1}{\cosh^2 u}\right)\cos v\right],$$

where

$$A=(\alpha-1)\ (1+\cos v_0)\cdot C,$$
$$B=A-C\cdot\cos^2 v_0,$$

$$C=-\frac{p}{2}\cdot\frac{1+\cos v_0}{1+(2-\alpha)\cos v_0+\cos^2 v_0},$$

$$a=\sin v_0, \qquad p=\frac{P}{\pi a^2},$$

$$\alpha=2\left(1-\frac{1}{m}\right),$$

$$h=\sqrt{\sinh^2 v+\cos^2 v}$$

m: poisson's number,

P: external load.

For the present experiments

$$\cos v_0=0.218,$$

so the constants become

$$A=-0.252\,p, \qquad B=-0.227\,p, \qquad C=-0.517\,p.$$

Thus the stress distributions in minimum cross-section are as follows;

$$\sigma_u=p\cdot\left(\frac{0.497}{\cos v}+\frac{0.025}{\cos^3 v}\right),$$

$$\sigma_v=p\cdot\left[\frac{1}{\cos v}\left\{\frac{0.252}{1+\cos v}+0.310\right\}-\frac{0.025}{\cos^3 v}\right],$$

$$\sigma_w=\frac{p}{\cos v}\left(0.537-\frac{0.252}{1+\cos v}\right).$$

These stresses for various sizes of specimens are plotted in Fig. 12.

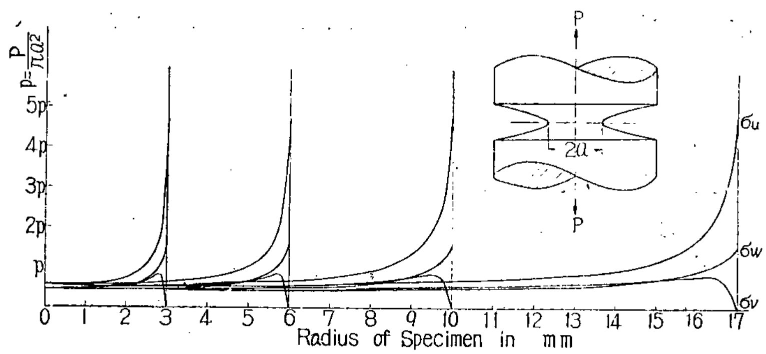

Fig. 12

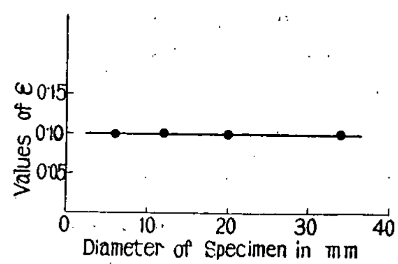

Fig. 13

As the notches of specimens used in the present experiments are geometrically similar and only different in sizes, the maximum stress at the tip of the notch becomes the values $4.68\,p$ for all sizes of specimens. However, the stress gradients are not the same; the smaller the size of specimen, the steaper the stress gradient.

As shown in Fig. 12, the stresses σ_v and σ_w are small compared with the stress σ_u in the vicinity of the root of notch, thus for the further discussions these two stresses σ_v and σ_w could be neglected.

Now, the fatigue limits of each size of specimen (in the notation mentioned above, p) were obtained by experiments, and from these values of p the distance ε, where the stress reaches to the fatigue limit of plain specimen, could be computed. Values of ε thus obtained are plotted in Fig. 13, and indicate that the values of ε are independent of the size of specimen and equal to 0.1 millimeter approximately.

This property that the distance ε is independent of the size of the specimen indicates that Moore's hypothesis for plain specimens under a reversed bending load is also applicable to notched specimens under a reversed direct load.

Isibasi derived theoreticaly the next relation:

$$\frac{1}{\sigma_n}=\frac{\alpha}{\sigma_p}\left[1+\frac{B}{\rho}+\frac{C}{\rho^2}\right]$$

where σ_n: fatigue limit of notched specimen,

σ_p: fatigue limit of unnotched specimen,

ρ: root radius of the notch,

α: form factor,

B and C: constants.

To examine this formula $1/\sigma_n$ and $1/\rho$ are plotted in Fig. 14. Clearly the relation between $1/\sigma_n$ and $1/\rho$ is parabolic. The curve drown in the Figure is the one for $B=-0.170$ and $C=0.0135$.

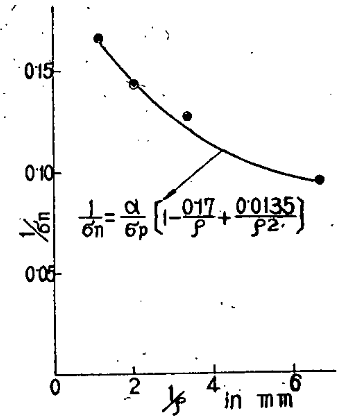

Fig. 14

VII. Summary

1. The fatigue strength under reversed diiect stresses of geometrically similar specimens of from 6 to 34 millimeter in diameter, containing a hypabolic groove, was greater for the smaller size of specimen.
2. It is confirmed that the size effect in fatigue is mainly due to the stress gradient in the specimens and that the critical factor to determine the fatigue strength of notched specimens is the stress slightly apart from the tip of the notch in the direction along which the stress gradient is maximum.
3. The distance ε for this material is equal to 0.1 millimeter apploximately and independent of the sizes of specimens.
4. The relation between $1/\sigma_n$ and $1/\rho$ is parabolic.

The values of ε might vary from one material to another with its grain size or other structural properties. To confirm this, another series of fatigue tests is now in progress.

Another important problem in fatigue of notched specimens is the subject of initiation and propagation of fatigue cracks. An experiment to investigate this problem is also in progress.

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